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BACKGROUND AIR QUALITY STUDIES OF THE POPLAR RIVER AREA OF NORTHEASTERN MONTANA

1977

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ABSTRACT

Two proposed 300 megawatt Saskatchewan power plants prompted the stepping up of air quality monitoring in the Poplar River area of northeastern Montana. Background monitoring was conducted for particulate matter, sulfur dioxide, and nitrogen dioxide. Other studies provided meteorology and visibility data. The air quality monitoring showed very low concentrations of all pollutants monitored. No sulfur dioxide was detected and only once was nitrogen dioxide detected. Particulate sampling showed a fair correlation with the monthly precipitation totals. No comparisons could be made of the Montana data with the Saskatchewan data as the latter was not available at this time. Recommendation was made for additional background sampling and additional analyses or comparisons.

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I. INTRODUCTION

On March 1, 1977, the Montana Department of Health and Environmental Sciences Air Quality Bureau stepped up their monitoring activities in the Poplar River area of northeastern Montana. The area is near the location of two 300 megawatt coal-fired power plants being built by the Saskatchewan Power Corporation. The plants are being constructed at Coronach, Saskatchewan about 5 miles north of the U.S. - Canada border. Concern was expressed by local residents of both sides of the border over the possible effects of the air pollutants to be emitted from the two power plants. Through funds made available by a special appropriation of the U. S. Congress, studies of various air and water effects were started in 1977. The Air Quality Bureau had been monitoring the air quality levels at one location prior to 1977. However, the air quality monitoring was increased to three sites during 1977. This report will investigate the results of that sampling and also results of sampling completed in Saskatchewan and other parts of northeastern Montana.

II. SAMPLING PROCEDURES

A. Instrumentation and Analysis

Sampling was conducted for suspended particulate matter (dust), nitrogen dioxide, and sulfur dioxide. These are the most abundant pollutants expected to be emitted from the power plants. In addition, other phases of the study provided meteorology and visibility data for correlation. The particulate matter was measured through the use of high volume samplers. The high volume sampler or hi-vol is used to measure total suspended particulates or particulates of size of 100 microns or smaller. Larger particles tend to settle out quickly and are not transported for great distances. The principal of collection was filtration of the suspended particulates. A vacuum sweeper motor pulls air through a glass fiber filter collecting the particulates as they pass through. Prior to use each filter was serialized and precision weighed under laboratory conditions. The filter was shipped to the sampling site where air was drawn through it at the rate of about one cubic meter per minute for 24 hours. Each hi-vol had a pressure transducer which recorded the actual flow rate and total time of operation for precise calculation of total volume sampled.

After the sampling had been completed, the filters were mailed back to the Air Quality Bureau in Helena for analysis. The sample data form was reviewed to insure that all necessary field information had been included. If there was any question concerning flow rates or sampling time, the sample was voided unless acceptable information could be obtained from the operator. If the information was complete the sample size was computed in cubic meters and the filter was delivered to the laboratory for gravimetric analysis.

In the laboratory the filter was inspected for physical damage. If the filter had holes, tears, or missing pieces from edges and corners, then it was voided. If the filter was not intact it was voided. If the filter was intact then it was equilabrated at laboratory conditions for 24 hours before weighing. During this time the relative humidity and temperature of the laboratory were continuously monitored. The filter was not weighed until it had equilabrated for 24 hours at laboratory conditions with the relative humidity less than fifty percent. The relative humidity of the laboratory averaged about 25 percent during this period.

Prior to weighing the filters the balance was checked to insure that it could weigh a 5 gr. weight within ± 0.5 mg of its stated weight (EPA, 1977). The weight had to conform to Class S standards and be tracable to a National Bureau of Standards calibration.

This weight plus the scale deflection check were recorded in the hi-vol Filter Final Weight logbook. The temperature and relative humidity at the time of weighing were recorded also. The filters were then weighed. Then one out of every five filters were reweighed by another person. If the weights agree within ± 5 mg then the lot was accepted (EPA, 1977). If there was a discrepancy the whole lot was reweighed.

When the gross filter weight had been determined then the tare weight was subtracted to give the net particulate weight in grams. This figure was then multiplied by 1,000,000 to convert to micrograms, and then it was divided by the cubic meters of air sampled. This gave the total suspended particulate value in micrograms of particulate per cubic meter of air (ug/m^3).

Then one out of ten calculations are checked by a third person as an audit on the final figure.

The only significant data losses occurred at the Richardson site where during the early summer birds kept trying to build nests on the hi-vol filters. Each time this occurred the sample had to be voided. No solution to the problem was discovered. The birds simply gave up after some time. Other data losses that occurred were due to samples being voided as part of the quality assurance program.

The nitrogen dioxide and sulfur dioxide were sampled through the use of a Research Appliance Company bubbler sampler. The sampler included a temperature control unit for the sulfur dioxide portion of the bubbler. The control unit kept the temperature of the bubbler solution between 7 and 17C. This was done to prevent loss of sulfur dioxide collected during the sampling because of the thermally unstable solution used in the collection method.

The bubbler method of sampling for sulfur dioxide and nitrogen dioxide consisted of preparing an absorbing solution in the laboratory. Separate absorbing solutions were used for sulfur dioxide and nitrogen dioxide. This solution was then mailed to the field sampling site where ambient air was bubbled through the absorbing solution by using a vacuum pump. The air flow through the solution was controlled by a critical orifice which was protected by a moisture trap and a filter. The pressure on the orifice was checked before and after sampling, and the flow through the orifice was calibrated with a Hastings Mass flowmeter before and after sampling. Samples were bubbled for 24 hour time periods and then the sample solution was mailed back to the laboratory.

Nitrogen dioxide was collected in a solution of sodium hydroxide and sodium arsenite. The nitrite ion produced during sampling was determined colorimetrically by reacting the exposed absorbing reagent with sulfanilamide and N-1 naphthylethylene diamine dihydrochloride.

Sulfur dioxide was absorbed from the air in a solution of potassium tetrachloromercurate, (TCM). This forms a dichlorosulfitomercurate complex which resists oxidation, but is thermally unstable. So sample handling, storage, and analysis were done at refrigerated temperatures where possible. The complex was then reacted with sulfamic acid to remove any interference from oxide of nitrogen. Then formaldehyde and pararosaniline dye were added to form intensely colored pararosaniline methyl sulfonic acid. The amount of this acid formed was measured spectrophotometrically. Fifty milliliters of absorbing solution bubbled at 200 ml/min for a 24-hour sample period would allow a range of 25 to 1050 micrograms of sulfur dioxide per cubic meter to be determined.

Data losses occurred with the bubbler sampling on two occasions. One time the extreme cold and blowing snow caused the solutions to freeze breaking some of the glass tubing. This problem was solved by adding an additional heating unit to keep the sampler just slightly warmer. The other data loss occurred when the pump unit simply stopped bubbling ambient air through the solution. The pump was returned to Helena for repair and some sampling time was lost due to this.

B. Site Location

In the air quality study there were three monitoring sites in the Poplar River area. The first site, called simply the Border Station, was located at the U.S.-Canada border some 14 miles north of Scobey and 5 miles downwind of the power plant (Fig. 1). This site included meteorology, visibility, and air quality sampling instrumentation. The air quality monitors located here were a high volume sampler and a wet chemistry gaseous bubbler. The meteorology and visibility equipment are discussed in the respective sections. The Border Station site (Fig. 2) consisted of a small 15-foot camper trailer converted into a sampling shelter. The air quality instruments were located on the roof of the trailer or some 10 feet from the ground. The area surrounding the site was fairly open with the only obstructions to wind flow to the north. To the north was located a small shelter of trees surrounding the Canadian customs office. These trees were at least 100 feet from the sampling trailer and did not obstruct the wind flow noticeably. The sampling site also provided an unobstructed view of the power plants which will be important in future sampling.

The pictures in Appendix B and the description in Appendix C describe views of the sampling site from several different angles demonstrating the ground cover and obstructions around the site. The majority of the ground cover is native grass for at least one-quarter mile around. Some wheat fields were located beyond that distance to the east and south. To the west the nearest fields were somewhat further. The only other local air pollution sources that could influence the results were the paved highway leading to Canada and a small barrel used to burn trash by the U.S. Customs Office. The highway contained a stop sign at both sides of the border resulting in fairly slow traffic speeds in the area. This consequently would tend to keep particulates emitted somewhat less than if the traffic continued on through at a high rate of speed. The trash barrel was located on the east side of the Customs Office and was determined not to affect the results of this location. Construction of a new Customs Office did occur during July and could have caused somewhat higher particulate levels at that time. No local sources of sulfur dioxide or nitrogen dioxide were determined to affect the results.

The Border Station site was moved from the location of 1976 (east of the Scobey Border Station) due to the close proximity to the trash barrel and being downwind of the highway. This move was made prior to 1977.

The second air quality monitoring site was located at the Frances Richardson farm approximately one mile north of Scobey. This site was also located adjacent to the paved highway. The site included only a high volume sampler. The sampler was located on top of a 10-foot platform some 50 feet west of the highway. The site was fenced in to protect it from grazing cattle as the site was located within a pasture. The description in the appendix describes the site from various directions. The description shows the openness of the sampling area and the ground cover. The majority of the cover was native grass with the nearest active field located across the highway to the southeast. The site was determined to be fairly free of particulate sources that would affect the results. The paved highway was not expected to influence the results.

The third sampling site was located on the Floyd Engberg farm. The site was 12 miles SE of the power plant site. The site was located to act as a sampling site in line with the Border Station site and downwind in the most predominant transboundary flow direction. The site included only a high volume sampler located on top of a platform 10 feet off the ground. The site was fenced in as it was located within a pasture containing cattle at various times of the year. The description in the appendix describes the site from various angles. The description shows that the ground cover was mainly native grass with the nearest particulate source of significance located 300 feet east. This source was a gravel road running north and south. Because of the distance from the sampler and being to the east (downwind during most of the year) it was determined that this road would not affect the sampling significantly.

All of the sampling sites were operated by Mike Machler. The sites had preset timers to allow the filters to be installed on the day prior to the sampling time. Mike Machler also calibrated the samplers. Electronic problems were handled mainly by Air Quality Bureau personnel in Helena.

As was mentioned previously, preset timers were used to allow the filters or bubbler solutions to be installed the day prior to sampling.

The timers would automatically turn on the sampler at midnight and run the sampler for 24 hours. Then the following day the samples were collected and mailed to Helena. The samples were taken once every six days at all the sites. This is the sampling schedule recommended by the Environmental Protection Agency.

Following analysis of the samples, the concentration data was coded onto computer forms, keypunched onto cards and run through a computer in Helena. The data was analyzed by the computer to calculate various statistics regarding the data.

III. SAMPLING RESULTS

The results of the gaseous sampling showed very low concentrations of sulfur dioxide and nitrogen dioxide. The levels were in most cases below the minimum detectable limit of the analysis method. No sulfur dioxide was detected in 45 samples taken. Nitrogen dioxide was detected only in one case and this was just above the minimum detectable limit. The minimum detectable limit for the analysis method was 0.01 parts per million (ppm) for sulfur dioxide and 0.005 ppm for nitrogen dioxide. Table 1 shows the results of this sampling for the Scobey and Fort Peck (see Figure 2) sites in northweastern Montana. Both sites showed similar results. As would be expected, the results are below all Montana, Federal and Saskatchewan ambient air quality standards (table 2).

Particulate sampling results are summarized in Table 3 for all the sites in the northeastern Montana area. All three of the sites in the Scobey area show similar results. The maximum 24-hour concentration was 107,100, and 109 micrograms per cubic meter at the three respective sites. The geometric averages were 20.6, 20.6, and 25.2 ug/m^3, respectively. The arithmetic averages were slightly higher being 29.0, 27.6, and 33.3, respectively. These results compared very similarly to the results measured at Fort Peck and Glendive. The Fort Peck and Glendive sites did have lower 24-hour maximum concentrations. These were 42 and 88, respectively. Table 3 also shows a frequency breakdown of the points as they would appear on a frequency diagram. Other statistics are also shown such as standard deviations and number of samples taken.

Table 4 shows a more simplified summary of the more important statistics for comparison with various ambient air quality standards. The accompanying table (Table 5) shows the various Montana, federal, and Saskatchewan particulate standards. The comparison shows that the 24-hour second highest particulate concentration is far below the Montana and federal standards. The highest 24-hour particulate concentration at all three sites does approach the Saskatchewan standard of 120 micrograms per cubic meter. The annual geometric means from all the sites fell well below all three air quality standards. The highest geometric mean was 25.2 ug/m^3 compared to the Montana standard of 60 ug/m^3.

Figure 3 shows a graph of the monthly geometric means of particulates for the three sites overlayed over a graph of the monthly precipitation totals for the same months. The trend in particulate levels is continually downward with much lower levels recorded toward the end of the year. The levels do correlate fairly well with the precipitation. Early in the year it was very dry and as the year progressed precipitation increased. Similarly early in the year particulate levels were high but as the year progressed the levels dropped.

Table 7 shows the precipitation amounts for Scobey for 1977 and the departure from the normal amounts. The amounts vary month by month with May through September as the wettest period during 1977. The spring of 1977 was very dry. Even June, which had 2.06 inches of precipitation, was almost one inch below normal. For the year Scobey was 0.05 inches below normal. The precipitation variation seems to have overshadowed any other seasonal effects such as crop stage, harvesting, etc. If future years are more normal regarding monthly precipitation, a seasonal variation should be analyzed.

Table 6 shows the monthly geometric means for suspended particulate matter measured in the area during 1977. These values are the same as those in Figure 3.

IV. COMPARISON WITH CANADIAN DATA

A comparison of particulate data for Montana with Saskatchewan was desired for this report. However, the latest data that could be obtained from Saskatchewan extended only through February, 1977 (Stobbs, 1977). Therefore, any comparison of 1977 data will have to be made next year provided the data can be obtained then.

Table 8 does show the results of samples collected from August, 1975, through February, 1977, by Saskatchewan. Sites 1, 2B and 4 show very similar results to those obtained by Montana. See Figure 1 for site locations. Precipitation may have played an important role here and this will have to be examined if the 1977 Saskatchewan data is received. One difference which was noted in the sampling was the location of the samplers. The Montana samplers are located on platforms from 10 to 15 feet off the ground. The Saskatchewan samplers are situated directly on the ground. Therefore, it would be expected that Canadian data would show much higher particulate levels than that actually occurring. This data should not be used to establish a baseline. Also at several sites in Saskatchewan the ground cover was poor with some tilled ground directly adjacent to the samplers. This was especially true of the sampler #4. The description in the appendix describes the Saskatchewan sites from various angles.

V. SUMMARY AND RECOMMENDATIONS

The air quality monitoring in the Scobey area showed very low concentrations of sulfur dioxide and nitrogen dioxide. The sampling also showed low concentrations of particulates despite 1977 being very dry for the early part of the year. Particulate levels correlated well with monthly precipitation amounts. Comparisons were not directly able to be done with Saskatchewan data as the Canadian data was over a different time period (August, 1975 - February, 1977). No standards were exceeded for any of the pollutants measured in northeastern Montana. The maximum 24-hour particulate levels for the Scobey area did approach the Saskatchewan standard.

It is recommended that the monitoring for the same pollutants be continued for another year to establish a better baseline. A comparison should be made of Saskatchewan particualte data for 1977 with Montana data for the same period. Precipitation should again be compared in 1978 with particulate levels. In addition with a full year's wind data, comparison should be made of wind speeds during particulate sampling with the particulate levels. Also, a comparison should be made of soil moisture content or drought index with particulate levels.

REFERENCES

Stobbs, R.A., 1977: Poplar River Power Station Ambient Suspended Particulate Matter. Interim Report #2, Environment Canada.

U.S. Environmental Protection Agency, 1977: Quality Assurance Handbook for Air Pollutant Measurement Systems, Vol. II - Ambient Air Specific Methods. Sec. No. 2.1.2 and 2.2.8, Revision No. 0.

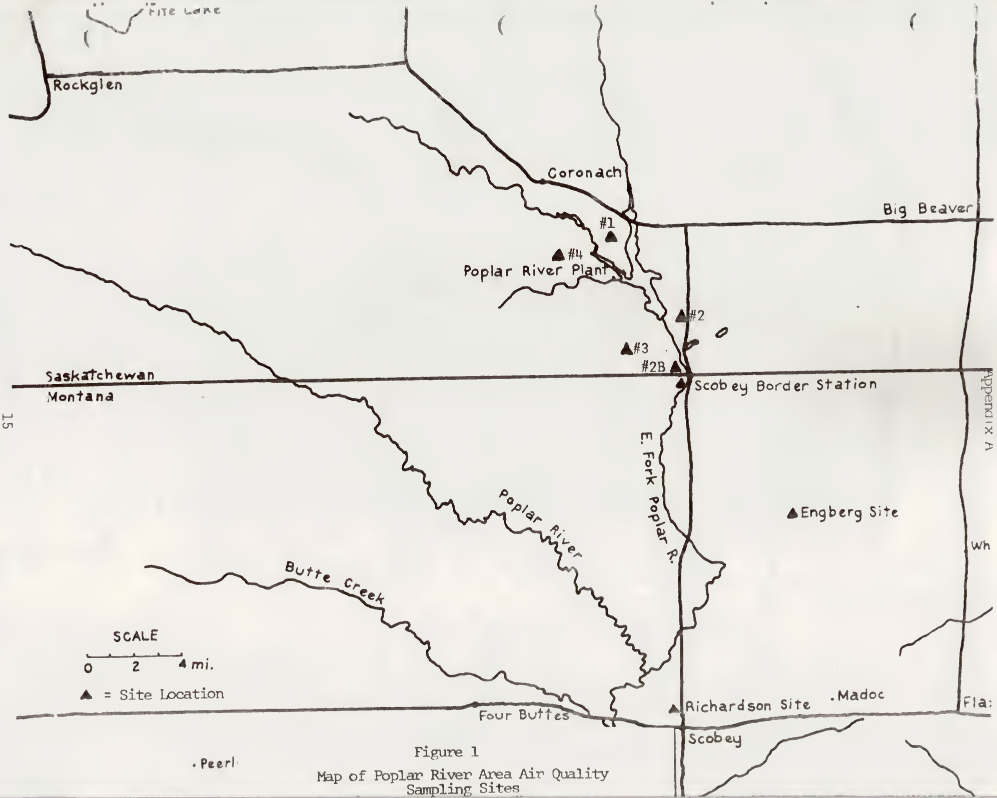


Figure 1

Map of Poplar River Area Air Quality Sampling Sites

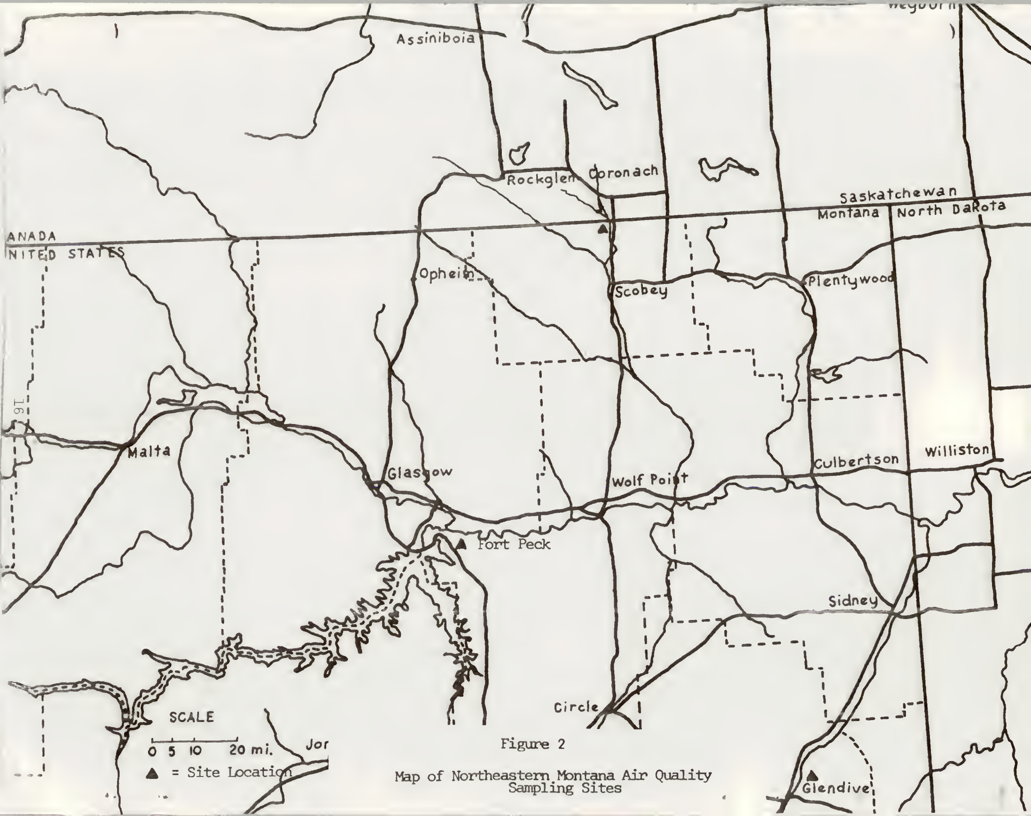


Figure 2

Map of Northeastern Montana Air Quality Sampling Sites

Table 1
Poplar River Nitrogen Dioxide and Sulfur Dioxide Data +
Jan. - Dec. 1977

Site	Nitrogen Dioxide * Max. Reading	Nitrogen Dioxide * Average	Sulfur Dioxide * Max. Reading	Sulfur Dioxide * Average	Number of Samples
Border Station Scobey	0.005+	<0.005	<0.01	<0.01	45
TV Hill Fort Peck	0.011	<0.005	<0.01	<0.01	33

* Readings in parts per million (ppm)
+ Minimum detectable limit is 0.01 ppm for sulfur dioxide and 0.005 ppm for nitrogen dioxide

Table 2

Comparison of Montana, Federal, and Saskatchewan Sulfur Dioxide Standards

Standard	Maximum 1-hour Concentration	Maximum 3-hour Concentration	Maximum 24-hour Concentration	Annual Average
Montana	0.25*	---	0.10*	0.02
Federal	---	0.50[a]	0.14[a]	0.03
Saskatchewan	0.17	---	0.06	0.01

Values in parts per million (ppm)

* Not to be exceeded more than once in 4 days

+ Not to be exceeded more than one percent of the days in a 3 month period.

a Not to be exceeded more than once per year

Comparison of[+] Federal and Saskatchewan Nigrogen Dioxide Standards

Standard	Maximum 1-hour Concentration	Maximum 24-hour Concentration	Annual Average
Federal	---	---	0.05
Saskatchewan	0.2	0.1	0.05

+ Values in parts per million (ppm).

Table 3
TOTAL SUSPENDED PARTICULATE CONCENTRATIONS*
Jan. 1977 - Dec. 1977

Station	Minimum	Frequency Distribution (Concentration equal to or less than stated %) 10%	30%	50%	70%	90%	95%	98%	Maximum	Arith. Mean	Arith. Std. Dev.	Geo. Mean	Geo. Std. Dev.	Total No. Obs.	Number of Samples Reported Per Month Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Border Sta Daniels Co	1	6	16	21	32	58	83	84	107	29.0	23.7	20.6	2.35	48	0	0	4	5	6	5	6	3	5	5	5	4
Richardson Daniels Co	4	6	14	21	31	67	80	95	100	27.6	22.8	20.6	1.87	44	0	0	4	1	6	5	5	4	5	5	5	4
Engberg Daniels Co	4	9	15	25	36	61	82	88	109	33.3	24.5	25.2	1.87	46	0	0	0	5	6	5	5	5	5	5	5	5
Microwave Glendive	3	8	15	19	24	33	41	41	42	20.8	10.6	17.8	1.48	26	1	0	2	1	0	5	3	2	2	5	3	2
TV Hill Fort Peck	2	4	8	14	30	53	72	75	88	24.6	22.4	16.0	2.64	34	0	4	2	2	1	0	5	4	4	5	4	3

*** Values in micrograms per cubic meter**

Table 4
Poplar River Area Total Suspended Particulate Data
Jan. - Dec. 1977

Site	Maximum * Reading	Second Highest Reading	Annual Geometric Mean
Border Station	107	84	20.6
Richardson	100	95	20.6
Engberg	109	88	25.2

* Values in micrograms per cubic meter

Table 5
Comparison of Montana, Federal and Saskatchewan Ambient Particulate Standards

Standard	Maximum 24-hour Concentration	Second Highest 24-hour Concentration	Annual Geometric Mean
Montana	---	200	60
Federal	---	260	75
Saskatchewan	120	---	70

Values in micrograms per cubic meter

Comparison of Monthly Levels of Suspended
Particulate Matter Versus Precipitation As
Measured in the Poplar River Area During 1977

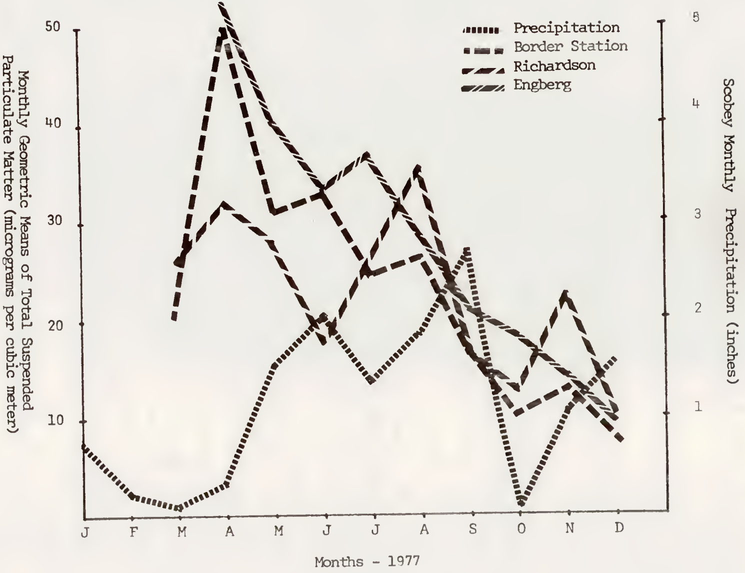


Figure 3

Table 6
Total Suspended Particulate Matter
Monthly Geometric Means for 1977

Month	Border Station	Richardson	Engberg
Jan	---	---	---
Feb.	---	---	---
Mar.	20.4	25.9	52.6
Apr.	49.8	32.0	52.6
May	30.8	27.7	39.9
June	33.1	17.3	33.1
July	24.8	26.9	37.0
Aug.	26.3	35.6	28.5
Sep.	16.9	16.8	20.9
Oct.	10.0	12.9	18.4
Nov.	13.0	22.5	14.2
Dec.	7.5	10.0	9.4

Values in micrograms per cubic meter

Table 7
Monthly Total Precipitation
Scobey - 1977

Month	Total (inches)	Departure from Normal (inches)
January	0.72	0.14
February	0.22	-0.28
March	0.12	-0.48
April	0.36	-0.63
May	1.54	-0.13
June	2.06	-0.98
July	1.35	-0.37
August	1.83	0.97
September	2.68	1.46
October	0.05	-0.57
November	1.08	0.66
December	1.56	1.06
Year	13.57	-0.05

Table 8
Saskatchewan Total Suspended Particulate Data +
Aug. 1975 - Feb. 1977

Site	Location from Power Plant	Maximum 24--hour Reading	Average
1	North	87	29
2*	East	233	78
2B	East	82	35
3	South	205	36
4	West	114	31

* Site 2 was moved to 2B on August 25, 1976

+ Reference Stobbs (1977)

APPENDIX A

Border Station Sampling Site

View from southeast

View from south

Border Station Sampling Site

View from north

Richardson Sampling Site

View from south

View from west

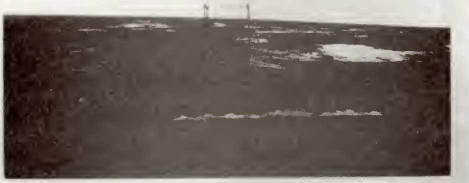
Richardson Sampling Site

View from north

View from east

Engberg Sampling Site

View from north



View from east

Engberg Sampling Site

View from south

View from west

Saskatchewan Sampling Site #1

View from north

View from east

Saskatchewan Sampling Site #1

View from south

View from west

Saskatchewan Sampling Site #2B

View from north

View from east

Saskatchewan Sampling Site #3

View from north

View from east

Saskatchewan Sampling Site #3

View from south

View from west

Saskatchewan Sampling Site #4

View from north

View from east

Saskatchewan Sampling Site #4

View from south

View from west

APPENDIX C

Sampling Site Critique

Montana Air Quality Stations

Border Station (See Figure 1 for locations)

a) View to north fairly unobstructed; small bushes some 100 feet N; tall trees same 300-400 feet N.

b) View to E unobstructed; U.S. Customs house some 200 feet SE.

c) View to S unobstructed.

d) View to W unobstructed.

Ground cover tall grass completely surrounding site. Paved highway 150 feet E of site. Unobstructed view of power plant to NW. Sampler is located on top of a 10 foot camper trailer.

Richardson Site

a) View to N unobstructed.

b) View to E fairly unobstructed; paved highway 50 feet E; tall trees 150 feet ENE.

c) View to S unobstructed; wheat field located 100 feet SW.

d) View to W unobstructed.

Ground cover is a pasture. Site is fenced in. Unobstructed view of power plant to N. Sampler is located on top of a 10 foot platform.

Engberg site

a) View to N unobstructed; small corral some 150 feet N.

b) View to E unobstructed; farm buildings 400 feet E; gravel road 300 feet E.

c) View to S unobstructed.

d) View to W unobstructed.

Ground cover is a pasture. Site is fenced in. Unobstructed view of power plant to NW. Sampler is located on top of a 10 foot platform.

Saskatchewan Air Quality Stations

#1 (See Figure 1 for locations)

a) View to N unobstructed, field some 100 feet N.

b) View to E unobstructed.

c) View to S unobstructed; hay storage about 100 feet S.

d) View to W fairly unobstructed; hay bales piled about 100 feet W.

Sampler enclosed in small fenced area. Ground cover sparse. Sampler should be elevated on platform to eliminate effect of sparse ground cover. Fairly unobstructed view of power plant to SSW.

#2B

a) Trees to N very tall and located only some 50 feet away; obstructs flow from NW through NE.

b) Customs house to E restricts effect of highway; house only 30-40 feet away; trash barrel for burning only 20 feet E.

c) Trees or shrubs to S fairly low and removed some 100 feet.

d) View to W unobstructed.

View of power plant obstructed by trees to N. Sampler should be elevated on platform and moved 150 feet W.

#3

a) View to N; no obstructions; fairly open.

b) View to E several small bushes fairly close (approximately 10 feet); house about 200 feet E.

c) View to S fairly open except several sheds about 100 feet S to SE.

d) View to W unobstructed; tilled ground about 50 feet W around small bushes.

Unobstructed view of power plant to NNW. Sampler should be elevated on platform.

#4

a) View to N fairly good. Shed some 10 feet tall located 30 feet N;various buildings and trees further N.

b) View to E unobstructed for at least 300 feet; trees at that point next to road on other side; directly next to sampler is tilled ground around small trees.

c) View to S obstructed by large bushes only 10-15 feet away.

d) View to W fairly unobstructed.

Power plant to SE; no clear view of plant, sampler on ground. Sampler should be moved to new location and elevated on platform.

II. METEOROLOGY

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ABSTRACT

The construction of two coal fired power plants at Coronach, Saskatchewan only four miles across the Montana border prompted a series of background studies to establish an air quality related background. Meteorological monitoring was just one of many studies conducted to provide a base for assessment of the effects of the power plants. Previous analyses of the power plants have relied on data from sites quite removed from the area. Upper air and surface meteorology were measured during 1977 at one location near the U.S. - Canada border. Analysis of the data are presented along with comparisons of previous data sources. Recommendations were made for additional monitoring to provide continuous measurements of stability and other additional meteorological parameters.

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I. INTRODUCTION

On March 1, 1977, the Air Quality Bureau of the Montana Department of Health and Environmental Sciences initiated air quality related studies near the location for two proposed power plants in southern Saskatchewan. The power plants will be 300 megawatt coal-fired plants being built by Saskatchewan Power Corporation near Coronach, Saskatchewan. Concern was expressed by Montana residents over the possible effects of the plants being built so close to the Montana border (plants are located only 4 miles north of the border). Through funds made available by special appropriation of the U. S. Congress, studies of various air and water effects were started or expanded during 1977. The Air Quality Bureau was given responsibility for six special studies. These were background air quality monitoring, upper air meteorology, background visibility monitoring, coal analyses, soil sampling and vegetation sampling.

This section will concentrate on one phase of the background study, that is meteorology. The northeastern Montana area has not had any detailed studies related to meteorology prior to the Poplar River Study. The National Weather Service does collect surface and upper air data at Glasgow, located some 70 miles SW of Scobey (Figure 1) (a section of this report will investigate the representativeness of the Glasgow data to the Scobey area). The Scobey area is generally flat with some small rolling hills and river drainages. The major river drainage in the area is the Poplar River. The area does not experience the same air pollution problems as western Montana due to the lack of the mountains and air pollution sources. The area is virtually void of large "point" sources of air pollution. The Scobey region is mainly agricultural with the major crop being wheat. The region does experience frequent morning inversions however they are seldom long lived except during winter months. The climate of the area could be considered continental with large temperature variations and low precipitation amounts.

II. INSTRUMENTATION AND DATA COLLECTION

A. General Discussion

To establish a meteorological data base, an initial study was designed to last for one year beginning in March, 1977. One primary station was established at the Port of Scobey (see fig. 2). The site was located only 5 miles SE of the proposed power plant site. The station included a 15 foot campler trailer for equipment and supplies storage. A breezeway was built onto the trailer to allow the filling of pilot balloons outside and yet free from wind influence.. The site contained instruments for measurement of surface wind, temperature, relative humidity, upper air wind and temperature lapse rate. The site also included two air quality monitors - a high volume particulate sampler and a sulfur dioxide and nitrogen dioxide bubbler sampler and visibility instrumentation. The site was located adjacent to the only paved highway in the immediate area which was fortunate for accessing the site during the winter months. Power was also closeby so no large distances had to be spanned. The site was also directly across the highway from the U.S. Customs Office Border Station which helped provide security for the site. The only problem that had to be dealt with at the site was a small air strip. The airstrip, running east and west along the border, had the closest end located approximately one quarter mile from the site. This closeness to the airstrip prevented the use of any large towers. The tower used was mounted on the top of the trailer and extended some ten feet above that point providing a total height of some 20 feet. Other than the air strip the only problem that the site caused was a short power loss when a piece of heavy equipment knocked down the power line near the border station.

Data was also obtained from the National Weather Service in Glasgow on surface and upper air meteorology. Data was also requested from the Environment Canada for meteorological data of the area, but this was not received at the final report date.

B. Meteorological Instrumentation

1. Surface Wind

The surface wind data recorded at the Port of Scobey was done by a Climatronics, Corp* Electronic Weather Station.+ The sensors were mounted on top of a 10 foot tower that was located on top of a camper trailer. The system provided a convenient package in that the wind speed, wind direction and temperature were all recorded on one chart located inside of the trailer. The temperature sensor was a naturally aspirated and shielded probe with an accuracy of ± 1.0 deg. F and a range of - 40 to +120 F. The wind speed sensor was a photo-chopper

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* Any mention of an equipment supplier does not constitute an endorsement.

+ For a short time an Aerovane wind sensor was used during the time the Climatronics system was down.

assembly that had two ranges, 0-50 and 0-100 mph. The 0-50 range was used throughout the study. The resulting accuracy was 0.5 mph. The threshold was 0.75 mph with a time constant of 8 ft. and a damping ratio of 0.4 - 0.6.

Several problems occurred with the system used. The first problem that occurred was the temperature card in the recorder was faulty and had to be returned to the factory for replacement.

The other problem that occurred caused a major loss of data. On May 4, 1977, at 1:30 p.m. a lightning strike on the power line caused a large power surge that damaged the wind recorder and sensors and the two solar radiation recorders. The solar radiation recorders were down only one week. The wind system recorder was returned to Helena three times for repair before it was realized that the photo-chopper assembly in the wind speed sensor was also damaged. The sensors were finally shipped to the factory for repair. A request was made to the Environmental Protection Agency for a temporary replacement system. This request was fulfilled and the temporary wind sensor was installed on September 7, 1977. As a guard against further lightning problems due to high level of thunderstorm activity in the area, highly sensitive circuit breakers were installed one week after the system was damaged. These breakers were tripped several times during the summer causing some data loss but preventing further large data losses due to damaged instruments. This preventive measure is recommended wherever high electrical activity occurs. Also a second wind sensor should be available as a backup unit. Due to the large amount of data loss, correlations were attempted for the periods where data was available to establish if another station could supplement the Border Station site. This element is discussed further under the analysis section. The Climatronics system was reinstalled on October 21, 1977, and remained in operation throughout the remainder of the study.

2. Surface Temperature and Relative Humidity

Surface temperature as mentioned under the preceding section was measured on the Climatronics Electronic Weather Station. Temperature was also measured with relative humidity on a Weather Measure hygrothermograph. The hygrothermograph provided an accuracy of 1 deg. C and 1% relative humidity. The system was calibrated weekly with a battery operated psychrometer. Periodically the hair bundle was cleaned with distilled water. The hygrothermograph was located some 25 feet from the trailer inside a standard weather shelter. The only significant problem with the hygrothermograph was caused by extremely cold temperatures. During these periods, the ink would freeze. Also calibration of the relative humidity caused a problem during the cold periods as the psychrometer used only went down to -15C. The very slow response of the hygrothermograph during these periods also caused problems. The response time was on the order of 8 hours at -30C. The temperature range of the hygrothermograph could be shifted only by 20C, which made the bottom of the scale -35C. Several times this temperature was not low enough as the ambient temperature dropped below this level. The instrument also became increasingly inaccurate as the temperature fell below -20C. At a temperature of -30C this error amounted to about 3C. An additional problem was that below -35C, the clock mechanism would freeze up. For the various reasons given, a shift was made to use the temperature sensor from the Climatronics system for the temperature readings.

3. Pilot Balloons

The upper level wind measurements were made through the use of pilot balloons launched from the Border Station site. Weather Measure theodolites and balloons were used on the program. The balloons used were 30 gram red balloons. The balloons released were precalibrated to a standard lift rate (see table 1). Even though dual theodolites were used in most cases, a calibrated lift rate was helpful as this provided a constant ascent rate for all the balloons released. A second advantage was when one tracker would lose a balloon, the second tracker would continue following the balloon. Then when analyzing the data, the balloon would be treated as a dual observation until the one operator lost the balloon, then the balloon would be treated as a single theodolite tracked balloon. After November 1, only single theodolites were used as the high school student used as the second tracker had to quit the work.

Balloons were launched one half hour after sunrise and again at approximately 2:00 p.m. for three days a week. Initially, observations were taken every 60 seconds on the balloon runs.

This was changed to every 30 seconds after October 1.

A Weather Measure pilot balloon timer with two portable walkie-talkie units were used to provide a signal for simultaneous balloon observations from the two trackers. Several times the radios failed causing a data loss. A twelve volt power supply was added to the system to provide more reliable power to the radios and this helped the situation. At temperatures less than -27C, the theodolites became too stiff to use. This caused some launches to be abandoned.

The observations were recorded on a standard form that provided for a recording of azimuths and elevations and other pertinent data.

The data was summarized using a method for dual measurements given by Thyer (1962). A complex computer program was written by the Air Quality Bureau and was used in the analysis. The program could handle single or dual observations, temperature sondes and a conversion of a run from dual to single observation due to a lost balloon by one tracker. The program provided a printed data analysis and could also provide several computer plots of the run.

4. Temperature Sondes

Temperature lapse rates were measured at the Border Station site through the use of a mini-temperature sondes. The minisondes used were manufactured by Aero-Aqua Inc. They were 403 MHZ FM sondes run on 9 volt batteries. The receiver used was manufactured by Climatronics Corp. The manufacturer also modified the receiver to accept signals produced by the Aero-Aqua minisondes. The minisonde receiver had a linear temperature output with automatic tracking, automatic scale switching and a folded monopole antenna.

Only one data loss problem occurred with the system and that was the pen assembly would stick when a scale change occurred causing a loss of data. The problem was due to the drive gear binding against a large driven gear. The drive gear assembly was lossened and moved back slightly, which corrected the problem. A second problem that was discovered but which did not in this case result in a data loss. This problem was that the minisonde used required a 40 foot string to suspend the sonde below the pilot balloon. A cotton string was used initially until it was discovered that the string readily absorbed water. This added weight would significantly affect the lift rate of the balloons. As a test a minisonde was launched in a light rain one morning. The balloon lifted off normally but after 8 minutes descended to the ground again. Since this project used dual theodolites and no launches were made during rain, showers, this problem did not affect the results here. Some pilot balloons did ascend into moisture-laden clouds, however. Conversion was made to a nylon string to prevent water absorption. The temperature sondes did cause some problems at low temperatures. Below -20C, approximately, at the surface, the sondes would not calibrate very well. The signal received appeared to be below the range of the receiver.

The minisondes were launched with the pilot balloons on three days a week twice a day.

D. Manpower

The Border Station site was operated by Mike Machler year round. He was in charge of operation and calibration of the instruments and data reduction to computer format. He was assisted on the dual theololite observations by a high school student on a part-time basis up to November 1. All electronic repairs were done in Helena by Air Quality Bureau staff or were sent to the factory for repair. Overall responsibility of the project was by Jim Gelhaus.

E. Data Reduction and Analysis

As was stated in the previous section; the on site meteorologist reduced all data to computer format. The data was then mailed to Helena where it was keypunched and summaried by programs written by the Air Quality Bureau. The computer used was the Montana Department of Highways IBM 370.

III. GENERAL AIR POLLUTION POTENTIAL

The meteorological study of the Poplar River area was designed with several objectives, however, the primary objective was to define the air pollution potential as related to the Poplar River Power Plants located near Coronach, Saskatchewan. Various key meteorological parameters were needed to adequately assess the impact of the power plants when the upper level winds were flowing from Canada to the U.S.A. (transboundary flow).

Other objectives of the meteorology study included a comparison of the surface and upper level meteorology of the Poplar River area with that of Glasgow, Montana and Rockglen, Saskatchewan. Glasgow is the nearest station that regularly measures upper level winds and temperature lapse rates. The Glasgow site is located some 70 miles southwest of the Scobey area. The measurement method used is also designed for measurement at extremely high altitudes and not designed to measure the lowest several kilometers in any detail due to the rapid ascent rate (about 300 m/min.). The Rockglen site is the nearest surface meteorological station that regularly takes measurements. This site is located some 35 miles northwest of Scobey. Question was raised whether the surface metheorology would be similar at the Rockglen and Scobey areas. Based on these two data sources, a comparison of the representativeness of the respective areas to that of the Poplar River area was needed. Future studies could then possibly rely on the Glasgow and Rockglen data if the data appeared representative of the Poplar River area.

A third objective of the meteorological study was to provide an adequate data base for assessment of any future developments on either side of the border. Possible potash developments in the Poplar River area could be assessed as to their impact on the air quality without further detailed background studies.

A fourth objective of the meteorological study was to provide a data base for correlations between data collected in the visibility and air quality studies. Various meteorological parameters affect the measurements made in these studies and without this data it could lead one to a false conclusion without the meteorological data to compare with.

The first three objectives will be addressed in this section. Correlations with visibility measurements are presented in the visibility section. Four general topics are addressed. These are surface meteorology, upper level winds, temperature lapse rates and mixing heights.

A. Surface Meteorology

The surface meteorology included the measurement or determination of temperature, relative humidity, stability, wind speed, and wind direction. The temperature and relative humidity were measured primarily through the use of a hygrothermograph as previously mentioned. Table 2 gives a quick summary of the measurements taken at the Scobey Border Station. The table shows statistics about maximum, minimum, and average temperature and averages of relative humidity for various hours. The values for temperature are given in degrees celcius or centigrade (C). The average maximum temperature was 12C with the highest temperature recorded on July 22 and August 24 as 33C. The minimum temperature was -37C recorded on December 9. July had the highest average temperature whereas December had the lowest average temperature (no data was available for January or February at report time). Table 2 also gives various statistics about the days that the maximum temperature was greater than 32 C and the days the maximum was less than 0C. These values were 4 and 46 respectively. Similar statistics are given for the minimum temperatures. The interesting statistic was that 29 days out of 31 for December had a minimum temperature less than -7C. Table 2 also gives the average relative humidity for 0600, 1200, 1800 and 2400 MST. The values show a typical diurnal trend with high humidities at night and early morning and lower humidities during the day. The average values for the year were 81, 47, 51 and 77 for 0600, 1200, 1800 and 2400 MST respectively.

Table 3 shows similar statistics for the 30 year normals at Glasgow, Montana. Comparison of Scobey for 1977 with the normal at Glasgow shows that the summer at Scobey was quite a bit cooler. For instance July average temperature at Scobey was 18C whereas the normal at Glasgow is 21C. The relative humidities for Scobey are very similar to the Glasgow normals. The only exception was December. At Scobey the December relative humidity remained near 85 percent all day whereas Glasgow shows this value to be closer to 75 percent all day. This may be due to the fact that December at Scobey was much colder than the normal at Glasgow. The low for December at Scobey for 1977 equalled the all-time low for December at Glasgow. The various statistics show the two areas to have fairly close temperatures and relative humidities especially for the year sampled.

For this study surface wind data from three sites was reviewed. These were the Scobey Border Station (or Port of Scobey), located at the international border 14 miles north of Scobey, MT; Glasgow, MT, located approximately 70 miles southwest of Scobey; and Rockglen, Sask., which is about 35 miles northwest of Scobey.

Measurements of wind speed and direction were made by the Air Quality Bureau at the Scobey Border Station from March 2 to May 4, 1977, and from September 8, 1977 on. The long interruption of data collection was due to a lightning strike which damaged the wind equipment. Wind data for the Glasgow Airport was obtained from the National Weather Service in Glasgow and is continuous from March 1, 1977. For Rockglen, seasonal wind roses for the period 1971-1973 were reviewed (Portelli, 1975).

Monthly and seasonal wind roses for Scobey and Glasgow were drawn showing the percent frequency of winds by direction. The percentage of calm conditions is noted, and the average wind speed for each direction is entered next to the appropriate spoke (Figures 3 through 9).

An examination of these wind roses shows that the frequency distribution of winds at Scobey was very similar from month to month. In all months, the most prevalent winds were from the W-NNW. Except for September and December, a secondary maximum from the SSE-SSW was noted. During September and December, this secondary maximum was from the E-ESE. For all months, the least common wind directions were NNE-ENE and SW-WSW. The average wind speed was greastest during March, April, November and December, and least during September, and October. The strongest average winds, 5-15 mps, were from the WNW-NNW, and the greatest monthly average wind speed was 14.4 m/sec from the NNW in November. The lightest average wind speeds, 1-2 m/sec, were from the N-ENE, and the smallest monthly average wind speed was 0.9 m/sec from the N in November.

Transboundary winds are those from WNW through ENE. Table 5 shows the percent frequency of transboundary winds by month and season. Transboundary winds occurred from 42-52%, of the time except for October and November, which showed 31 and 39 percent respectively. Most of the monthly variation in transboundary flow was due to variations in the frequency of winds from the NE quadrant, as northwest wind frequency remained almost constant. Table 6 shows the average speed of transboundary winds. Average transboundary wind speed varied from 1.6 mps to 4.5 mps, with the highest values in March, April, November and December and the lowest values in September and October.

In Glasgow, as in Scobey, the wind roses show little difference from month to month. The most common wind directions were W-NNW and E-SE. South winds were much less common here than in Scobey. This may be due to a channeling effect of the river valleys, which run north-south in the Scobey area and east-west in the Glasgow area; however, relief is small in both areas, only 60 to 100 meters and there is little difference in the northwest components of the wind between the two areas. The least common wind directions were NNE-ENE and SSW-WSW. The average wind speed is greater here than in Scobey, varying from 3 to 9 mps. The strongest winds are from the W-NNW and E-SE while the lightest were from NNE-ENE and SSW-WSW. The only significant exception was in March when NNE-NE winds were very strong, averaging over 9 mps. Transboundary winds occurred from 38 to 54 percent of the time, except for May and October, which had 31 and 33 percent, respectively. As in Scobey, variations in frequency of NE winds accounted for most of the monthly variations of transboundary winds. The average speed of transboundary winds in Glasgow was considerably higher than in Scobey and varied from 4.1 mps in September to 6.1 mps in March. All months except March had values between 4.1 and 4.9 mps.

The Rockglen wind roses (Portelli, 1975) did not show a strongly bipolar arrangement as do Scobey and Glasgow. The most common Rockglen wind directions were from the WSW-NNW and from the SSE-S. Southwest winds were much more common than in either Scobey or Glasgow. The least common wind directions at Rockglen were NNE-ESE. Wind direction did not vary much from season to season, except that winds from the SSE-SSW appeared to be less common in winter, while WSW-W winds were more common. The average yearly wind speed was 5.9 mps. The highest average winds, 6-7.5 mps were from the W-NNW and from the SSE. Lowest speeds, 3-4 mps, were from the NE-ENE. The average wind speed at Rockglen was slightly higher than Glasgow and considerably higher than Scobey. Transboundary winds blew about 41-43% of the time throughout the year. The average speed of transboundary winds was 5.3-5.5 mps in spring, autumn, and winter, and 4.7 mps in summer.

An examination of the Border Station wind records for relatively still nights where a drainage wind pattern could possibly be seen showed that there is no clearly identifiable pattern. Wind direction during these nights was almost random. There may have been a slight tendency to winds in the 70°-120° range which could have been a drainage pattern, but this cannot be positively stated. Relief in the area is small, amounting to only about 60 meters within 8 km and 150 meters within 15 km of the site.

In many of the diffusion or simulation models used in analysis of air pollution sources, a one-hour concentration is calculated based on meteorology, emission or source parameters and other criteria. The one-hour concentration is then often converted to three-hour or twenty-four hour concentrations using a time averaging coefficient. The coefficient assumes a persistence of the wind blowing within a certain degree sector for a given time period. An example is a coefficient could assume the wind blew for 6 hours from the north and then blew from a different direction such as south for the remaining 18 hours in a 24-hour period. This coefficient is based on review of various data collected from wind sensors located at different sites. In an attempt to define a factor which would characterize the transboundary flow that would cause the greatest impact on Montana, a Time Average Factor has been derived.

Time Average Factor $= T_{af}$

$$T_{af} = \frac{\text{No. of hours wind blew within a 22.5 deg. sector in a given period}}{\text{Length of given period}}$$

The two periods that are of the most importance here are the three and twenty-four hour periods when the wind is blowing transboundary from Canada to the U.S. Table 7 gives the monthly high and second high values of T_{af} when the wind was blowing in the same 22.5

degree sector. Also shown is the average wind speed during the periods.

Atmospheric stability was determined from the scheme designed by Turner (1964) for deriving the Pasquill stabilities. This method relied on cloud cover, cloud height, sun declination, surface wind speed and solar radiation. With the data available at the Border Station no stability scheme was available to prepare an hourly frequency. Stabilities could have been prepared from the temperature soundings and wind speeds. However, this method would have only given two stabilities three days a week. No measurement of cloud cover or cloud height was available at the Border Station. A decision was made by the Air Quality Bureau to obtain all the necessary data from Glasgow and prepare a stability summary for that area. At least some sort of stability distribution would be available. The problem with the other schemes available is that a tall tower (greater than 40 meters) and fully instrumented is necessary to determine stability. It is proposed that if additional monitoring is done in the Poplar River area that a stability scheme be developed to give an hourly frequency distribution. Possible use could be made of surface meteorology in conjunction with an acoustic radar.

Table 8 summarizes the monthly frequency of the various stabilities. A stability of A is very unstable and a stability of F is moderately stable. The remainder of the letters refer to stabilities in between. The monthly summaries show very high occurrence of D or neutral conditions and very low occurrences of unstable conditions.

This distribution is over weighted to the neutral conditions. This fact of the Turner classification scheme has been noted before by various authors.

B. Upper Level Winds

Pilot balloons were launched six times weekly at the Scobey Border Station, and from these flights wind speed and direction as a function of height was computed. Wind roses were drawn for two levels, 107m and 321m, showing the percent frequency of winds by direction (Figures 10 through 17). As with the surface wind roses, the average wind speed for each direction is entered. Of course, these roses represent a much smaller sample than the surface wind roses due to the less frequent observations. Tables 9 through 12 show the statistics for the wind roses.

At the 107 meter level, the most common wind directions were WNW-NNW during most months, excpet for April and May, when S-SW winds were most common. A secondary maximum from the SE-WSW was noted in June, August, and September, from the S-SW in July, from the SSW-WSW in October and November and from the NE-SE in December. Average wind speeds were somewhat higher than at the surface and the highest values, 10-22 mps, were from the WNW-N. Lightest winds, averaging 2-5 mps, were generally from the NE and SW quadrants. Transboundary flow was more common at this level than at the surface, although during April and September it was less common. Percentage frequency of transboundary winds did not vary significantly with season, averaging about 49% and varying from 32% in April to 61% in August. The average speed of transboundary winds ranged from 4 mps in July to 11 mps in November. A seasonal trend is apparent, with lighter winds in the summer and stronger winds in other seasons.

At the 321 meter level, the most common wind directions were SW-NW in April; WNW-N in May and June; W-NW in August, October, November, and December, NNW in July, and no clear trend in September. The secondary maximum was from the SE-S in April and June, ENE-S in July, S-WSW in August and November, SSW-SW in October, and ENE-SW in December. Average wind speeds were higher than either the surface or the 107 meter level. The highest winds, averaging 12-19 mps were from the NW and SE quadrants, while the lowest values, 1-4 mps were generally from the NE, except for August, when winds from the SE were very light. The frequency of transboundary flow at this level was intermediate between the frequencies of the surface and 107 meter levels, averaging about 45%. Monthly averages varied from 35% in July to 67% in December. The average speed of transboundary winds was 7.4 mps in summer and 9.5 mps in autumn. Monthly averages ranged from 5.8 mps in September to 11.7 mps in May and October.

C. Mixing Heights

Tables 13 through 18 show the percent frequency of morning and afternoon mixing heights for the Scobey Border Station by month and season.

In the mornings, mixing heights of 0-100 meters were most common in all months except August, averaging about 51% and ranging from 38.5% in August to 70% in April. The next most common mixing heights were from 101-250 meters for all months except May, July and November, when they are 251-500 meters, 251-500 meters and > 1500 meters, respectively. In all months morning mixing heights were less than 500 meters most of the time, averaging 83%, and ranging from 64% in November to 100% in July. Mixing heights greater than 1500 meters did not occur during June through September, inclusive, and in December; and occurred an average of 14% of the time in April, May, October and November.

The most common afternoon mixing heights were those greater than 1500 meters, except for December, when mixing heights from 1-100 meters were most common. Mixing heights greater than 1500 meters occurred 37% of the time, and ranged from 0% in December to 61.6% in July. A seasonal variation is clearly apparent here: mixing heights above 1500 meters are much more common in summer than in winter. During April through October, inclusive, afternoon mixing heights were greater than 1000 meters 60% of the time, ranging from 16.7% in May to 85.7% in August. During November and December, however, mixing heights over 1000 meters occurred only 23% of the time. Mixing heights less than 500 meters occurred 64% of the time in November and December, but only 22% of the time in April through October.

Table 1.9 shows the average seasonal morning and afternoon mixing heights for Glasgow, Montana. The measurements were taken at 0500 and 1700 MST. Comparing the summer and fall seasons with the Scobey Border Station data, the morning mixing heights compare fairly well. It is difficult to make a direct comparison as the Glasgow data is taken at a slightly different time and also use the minimum temperature plus 2.5C whereas the Border Station measurements used the minimum temperature plus 3.0C. This can make a difference in the mixing height. The afternoon mixing heights are quite different although it is difficult to compare due to the type of statistics. Many times on the Scobey Border Station the mixing height was unlimited. That is the mixing height was above the highest measurement level. It is recommended that if further observations are taken, the entire year and corresponding seasons should be looked at. If possible observations should also be taken to a greater elevation possibly using stronger transmitters.

D. Temperature Lapse Rates

Seasonal tables showing the frequency of occurrence of inversions (classified according to the Holzworth classification scheme for inversions) are shown in tables 21 through 36 for Scobey and Glasgow. These tables also show the frequency of occurrence of inversion thickness versus inversion base height (Holzworth, 1974).

Inversions were classified as inversion types 1-5, the type 1 being the weakest and type 5 the strongest inversion (see table 20). An examination of the tables shows that the morning inversions were mainly surfaced bases with a thickness ranging from 100 to 500m.

These were mainly Holzworth type 3 or 4. Looking at the various seasons for the morning inversions, all four seasons appear to have similar distributions. In the spring season the most common thickness is 251-500m whereas in the summer it is 101-250m and in the fall it is 1-100m. It is all worth noting that when there was a morning surface based inversion there was also air inversion aloft with bases mostly from 100 to 750m above ground. These were usually weaker and thinner inversions than the surface based inversions.

Examining the afternoon inversions shows very few surface based inversions except in December. The inversions are mainly Holzworth type 1, 2 or 3 with very few type 4 inversions. Very few days had no inversions at all. This occurred on only 13 out of 227 cases examined here. The thickness of the inversions were mainly 100m or less with very few greater than 250m. The bases of the inversions for the afternoon soundings were spread very widely from 100 to 2500m. The stronger afternoon inversions were mainly based from 250 to 500m aloft.

Comparison of the Border Station sounding with that of five years data from Glasgow (1971-1975) is presented in tables 28 through 36. The Glasgow morning soundings are run at 0500 MST whereas the evening soundings are run at 1700 MST. With this in mind, the morning soundings at Glasgow demonstrate an average thickness greater than that at the Border Station with the most frequent thickness as 251-500m. There also appears a higher percentage of surface based inversions in the mornings at Glasgow. Around 70% of the mornings at Glasgow there is a surface based inversion. There also appeared a fairly small percentage of second inversions aloft in the mornings at Glasgow. This fact is probably due to the instrument used at Glasgow. The radiosonde used at Glasgow rises very rapidly and is not as sensitive to small inversions (weak and thin) as the minisondes used at the Border Station. Many of the inversions aloft at the Border Station were weak and fairly thin.

Looking at the afternoon inversions at Glasgow a similar problem is noted. The Glasgow data shows a high percentage of afternoons had no inversion present (as high as 67 percent in the summer). These results differ very much from the Scobey results. Very few afternoons at Scobey had no inversion. This is again probably due to the instrument used. Many of the elevated afternoon inversions were fairly thin and weak. These probably are not detected by the radiosonde at Glasgow.

IV. SUMMARY AND RECOMMENDATIONS

The primary objective of the meteorological study in the Poplar River area was to define the air pollution potential as related to the Poplar River Power Plants located at Coronach, Saskatchewan. The most significant points that affect the power plant emissions moving toward Montana are: transboundary winds, which blow about 45% aloft at an average speed of 5-10 mps at the surface and 8-14 mps aloft; mixing heights, which generally are less than 500 meters in the morning and greater than 1500 meters in the afternoon, except for December when afternoon mixing heights are generally less than 100 meters; and the frequency, thickness and strength of inversions, particarly those based at or near the surface, which generally are type

3 or 4 inversions from 101 to 500 meters thick, except for November and December when inversions less than 100 meters thick were more common.

The second objective of the meteorological study was to compare the meteorology of the Scobey area to that of Glasgow, Montana, and Rockglen, Saskatchewan. The surface meteorology, especially surface wind speed, appears significantly different enough at the various sites to preclude the use of the Rockglen or Glasgow data in describing the Poplar River area. The upper air meteorology with respect to vertical temperature changes also appears significantly different at Scobey from that of Glasgow. This may be due primarily to the instruments used at the various sites.

The third objective of the study was to provide an adequate data base for assessment of future developments in the area. We feel this objective is not fully completed. Only nine months or less of data was collected through December of 1977. This is not an adequate data base for future assessments.

Recommendation is made for an additional year of background monitoring to provide a better definition of the air pollution potential of the Poplar River Power Plants and to provide a better data base for future assessments. Additional monitoring is also needed to provide a local definition of stability patterns.

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APPENDIX

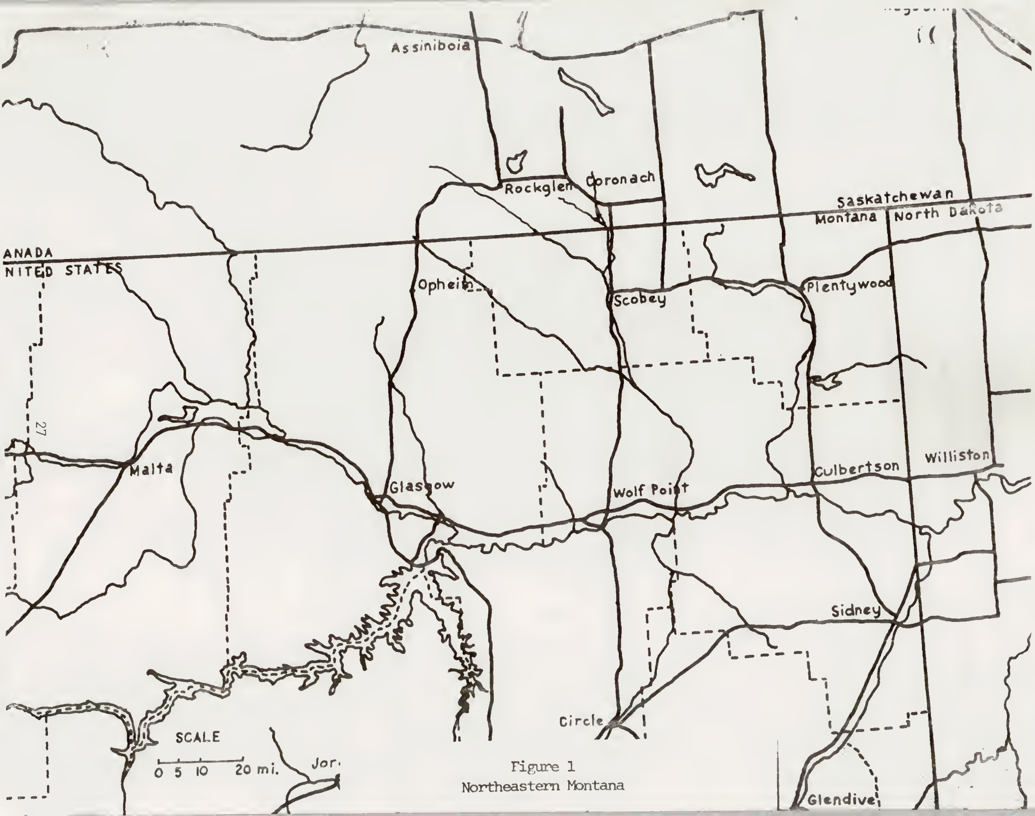


Figure 1
Northeastern Montana

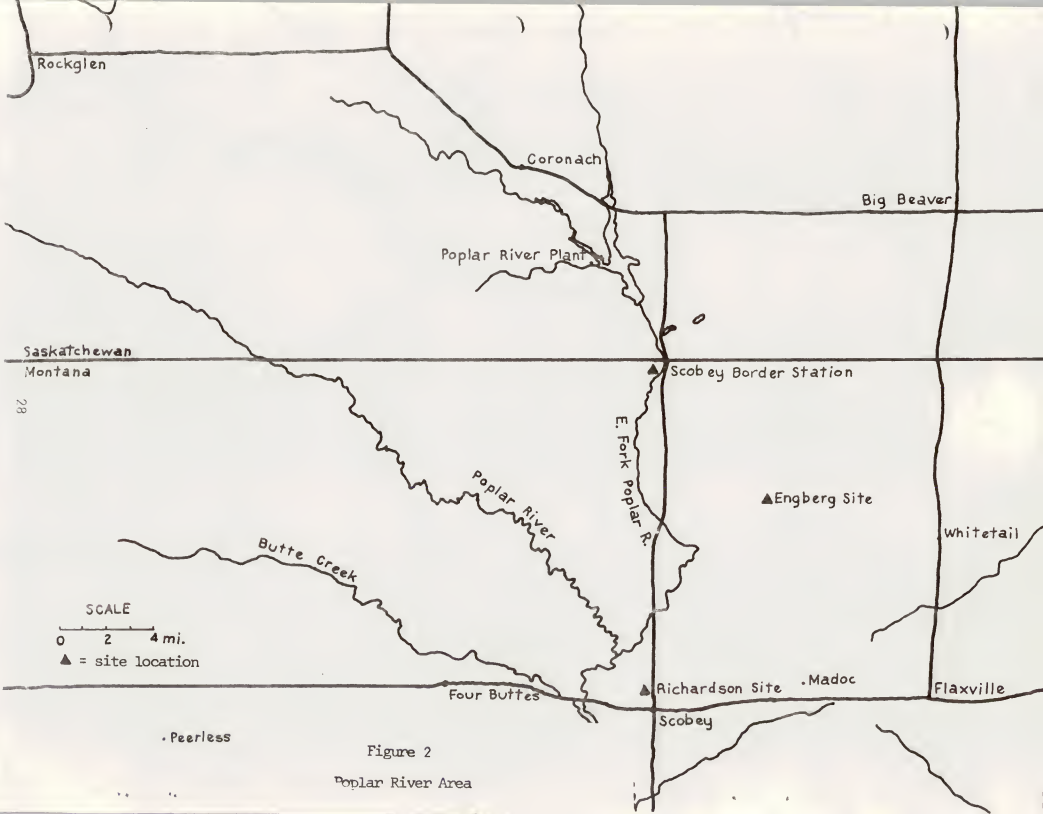


Figure 2

Poplar River Area

Table 1

Lift Rates For Various Balloons*

Weight No.	Weight (g)	Lift Rate (m/sec)+
1	72.0	2.75
2	33.9	1.78
3	15.0	1.28
4	5.7	0.78

* Rates apply to Weather Measure 30g balloons only.

+ Reference Super (1972).

Table 2

```
                         METEOROLOGICAL DATA FOR THE CURRENT YEAR

AREA: SCOBEY        SITE: BORDER   TIME USED: MTN STANDARD    LATITUDE: 49
      LONGITUDE: 105 25         ELEV.(MSL):  745 M    YEAR: 1977      MONTH:

         AVERAGE TEMP          EXTREMES               DEGREE DAYS     RELATIVE HUMIDITY
MONTH    DAILY  MONTHLY      (TEMPERATURE)             (BASE 18)       HR   HR   HR   HR
          MAX MIN          HI  DATE  LOW  DATE    HEATING COOLING      06   12   18   24


 MAR       5  -6    0      14  23    -17  20         546       0       78   40   45   70
 APR      13  -1    7      27  26    -12   3         316       0       72   26   32   62
 MAY      21   6   14      31  13     -3   1         142      15       75   38   39   73
 JUNE     22  10   16      31   7      7   3          72      19       75   46   45   76
 JULY     25  11   18      33  22      5   1          34      41       80   43   40   77
 AUG      20   7   14      33  24      0  17         138       3       86   47   45   82
 SEPT     17   5   11      27   7      1  27         221       0       94   59   62   89
 OCT      12   0    5      21  16     -8  11         392       0       82   44   56   76
 NOV       0 -11   -5      15  12    -29  25         707       0       83   54   66   79
 DEC      -9 -17  -13       3  11    -37   9         958       0       87   81   86   87

YEAR      12   0    6      33        -37            3526      78       81   47   51   77


         DAYS MAX TEMP    DAYS MIN TEMP    NO. DAYS DATA
        32 DEG   0 DEG     0 DEG  -7 DEG  POSS-  WITH 20 OR
        & OVER  & BELOW  & BELOW & BELOW  IBLE    MORE HRS


 MAR       0       5       29      14      31      29
 APR       0       2       20       2      30      30
 MAY       0       0        2       0      31      31
 JUNE      0       0        0       0      30      30
 JULY      3       0        0       0      31      31
 AUG       1       0        1       0      31      31
 SEPT      0       0        0       0      30      30
 OCT       0       0       21       1      31      31
 NOV       0      11       29      21      30      30
 DEC       0      28       31      29      31      31


YEAR       4      46      133      67     306     304


***  AVERAGES,DEGREE DAYS, AND DAYS MAX AND MIN TEMP ARE BASED ON
 DAYS WITH 20 OR MORE HOURS DATA.

***  DEGREE DAY IS DEFINED AS THE DAILY AVERAGE TEMP - 18
 WHERE NEGATIVE VALUES INDICATE HEATING DAYS.

***  RELATIVE HUMIDITY VALUES ARE AVERAGES OF THE RELATIVE HUMIDITY
 AT THE HOUR INDICATED OVER THE ENTIRE MONTH.
```

Table 3

Glasgow Normals, Means, and Extremes of Temperature and Relative Humidity

	Average Temperature			Extreme (Temperature)		Relative Humidity			
	Daily								
Month	Max.	Min.	Monthly	Hi	Low	Hr	Hr	Hr	Hr
Jan.	-7	-18	-12	13	-44	72	69	69	71
Feb.	-4	-16	-10	14	-30	77	74	73	78
Mar.	3	-9	-3	24	-27	77	66	61	74
Apr.	13	-1	6	29	-19	78	56	50	70
May	20	6	13	33	-4	72	46	39	61
June	23	10	17	35	1	78	51	44	68
July	30	13	21	39	5	76	46	36	62
Aug.	28	12	20	39	4	66	40	30	50
Sep.	21	6	14	36	-3	72	47	37	61
Oct.	14	0	7	31	-8	73	51	45	64
Nov.	3	-8	-2	24	-28	78	67	64	73
Dec.	-3	-13	-8	12	-37	77	72	72	76
Year	12	-1	5	39	-44	75	57	52	67
Year (Mar-Dec)	15	2	8.5	39	-37	75	54	48	66

Table 5
TRANSBOUNDARY WINDS (WNW-ENE) PERCENT FREQUENCY

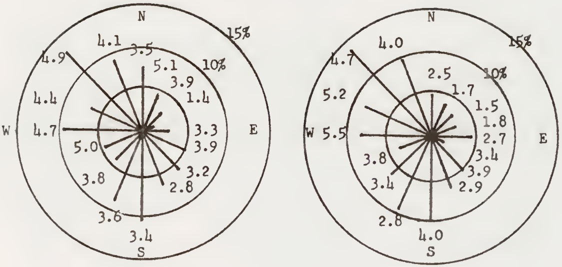
		Scobey			Glasgow	Rockglen
	surface	107 m	321 m		surface	surface
1977 Mar	42.4				41.9	
Apr	45.4	31.8	39.0		43.6	
May		36.4	44.4		30.8	
June		41.7	47.6		43.3	
July		44.0	35.6		45.2	
Aug		61.5	49.9		53.8	
Sep	52.1	43.3	38.2		38.0	
Oct	31.0	54.3	47.4		33.5	
Nov	39.2	49.9	56.4		38.3	
Dec	52.1	58.8	66.7			
Summer		49.1	44.4	Spring	39.2	43
Autumn	40.8	49.2	47.3	Summer	47.4	42
				Autumn	36.6	41
				Winter		43

Table 6

TRANSBOUNDARY WINDS (WNW-ENE) AVERAGE WIND SPEED

		Scobey		Glasgow	Rockglen
	surface	107 m	321 m	surface	surface
1977 Mar	3.9			6.1	
Apr	3.1	6.8	9.4	4.7	
May		7.4	11.7	4.5	
June		5.8	8.9	4.9	
July		4.0	6.9	4.9	
Aug		5.0	6.4	4.2	
Sep	1.6	4.5	5.8	4.1	
Oct	1.7	6.3	11.7	4.2	
Nov	4.5	11.0	10.9	4.6	
Dec	3.8	7.2	9.8		
Spring				5.1	5.5
Summer		4.9	7.4	4.7	4.7
Autumn	2.6	7.3	9.5	4.3	5.3
Winter					5.3

Values in meters per second.



March 1977

Calm 1.0%

April 1977

Calm 1.8%

FIGURE 3

MONTHLY WIND ROSES

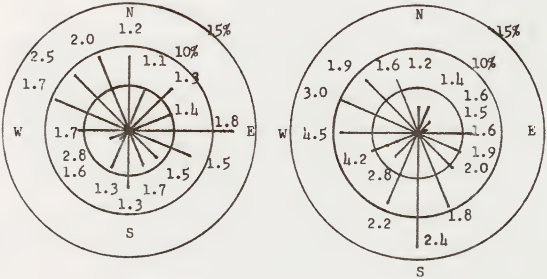
SCOBEY BORDER STATION, MONTANA

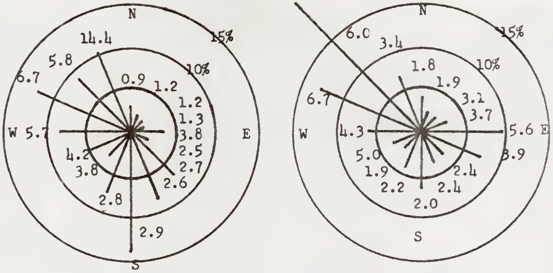
September 1977

Calm 1.7%

October 1977

Calm 3.1%





November 1977

Calm 4.6%

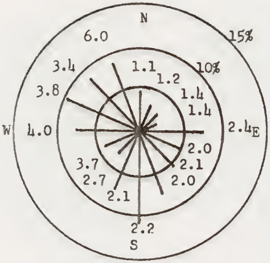
December 1977

Calm 1.9%

FIGURE 4

MONTHLY WIND ROSES

SCOBEY BORDER STATION, MONTANA



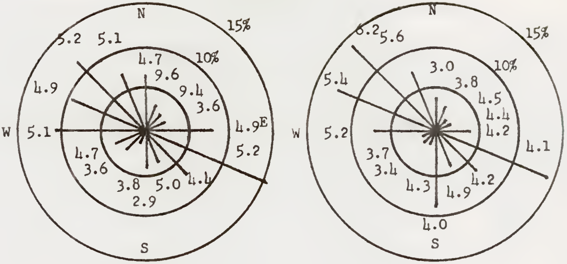
Autumn 1977 (Sep-Nov)

Calm 3.1%

FIGURE 5

SEASONAL WIND ROSES

SCOBEY BORDER STATION, MONTANA



March 1977

Calm 2.0%

April 1977

Calm 3.5%

FIGURE 6
MONTHLY WIND ROSES

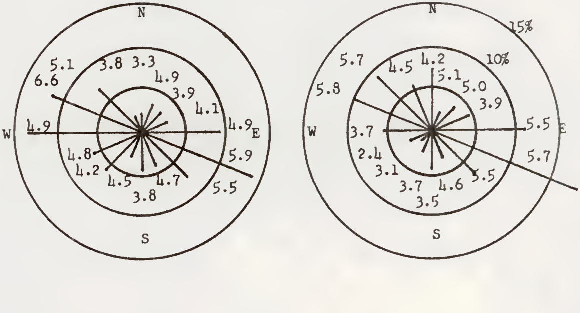
GLASGOW, MONTANA

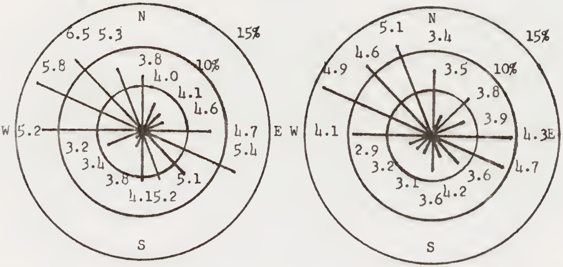
May 1977

Calm 2.0%

June 1977

Calm 2.5%





July 1977

Calm 2.3%

August 1977

Calm 2.7%

FIGURE 7

MONTHLY WIND ROSES

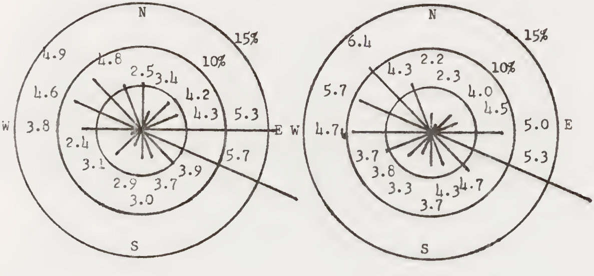
GLASGOW, MONTANA

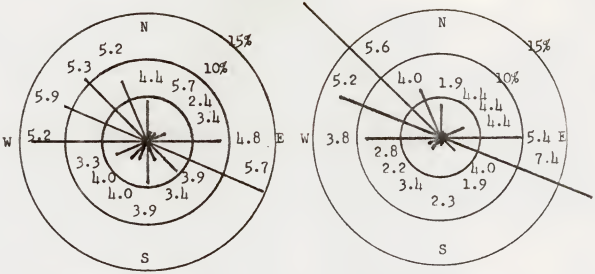
September 1977

Calm 3.1%

October 1977

Calm 2.7%





November 1977

Calm 5.1%

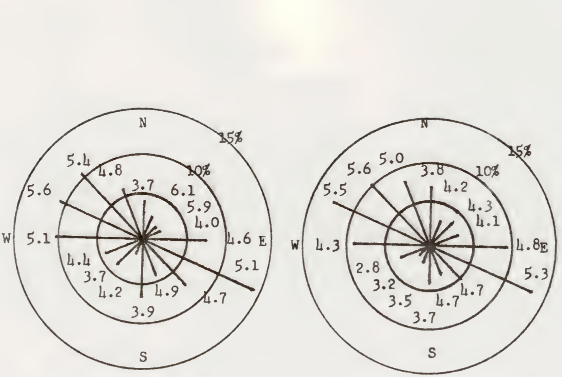
December 1977

Calm 4.4%

FIGURE 8

MONTHLY WIND ROSES

GLASGOW, MONTANA



Spring 1977 (Mar-May)

Calm 2.5%

Summer 1977 (Jun-Aug)

Calm 2.5%

FIGURE 9

SEASONAL WIND ROSES

GLASGOW, MONTANA

Autumn 1977 (Sep-Nov)

Calm 3.6%

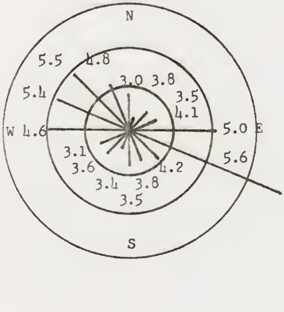


Table 7

Poplar River Area Time Average Factor For Transboundary Flow

			3-Hour Period					24-Hour Period		
Month	Sector	High	Aver. Wind Speed (m/sec)	2nd High	Aver. Wind Speed(m/sec)	Sector	High	Aver. Wind Speed (m/sec)	2nd High	Aver. Wind Speed (m/sec)
Mar.	310-330	1.00	5.1	1.00	5.3	310-330	0.92	5.4	0.58	5.1
Apr.	310-330	1.00	5.8	1.00	5.8	310-330	0.75	3.7	0.58	5.1
Sep.	310-330	1.00	5.0	1.00	4.7	310-330	0.75	3.5	0.46	5.4
Oct.	300-320	1.00	5.8	1.00	5.7	290-310	0.75	1.3	0.67	2.8
Nov.	310-330	1.00	5.3	1.00	5.3	320-340	1.00	5.1	0.79	9.0
Dec.	310-330	1.00	5.3	1.00	5.5	290-310	0.88	6.3	0.83	7.2

Time Average Factor = T_{af}

$$T_{af} = \frac{\text{No. of hours wind blew within a 22.5 deg. sector in a given period}}{\text{Length of given period}}$$

Table 8

Monthly Summary of Pasquill Stabilities
For 1977 at Glasgow, Montana

	Percent Frequency of Occurrence					
Month	A*	B	C	D	E	F
Mar	1	3	6	60	16	11
Apr	3	5	14	44	17	15
May	3	7	17	52	12	6
June	1	8	17	52	11	8
July	3	6	18	51	11	8
Aug	3	6	13	47	17	11
Sep	3	6	8	56	14	11
Oct	0	2	4	62	17	13
Nov	0	0	2	64	12	19
Dec	0	0	2	69	16	11
Average	2	4	10	56	14	11

* A stability refers to very unstable whereas F stability refers to moderately stable.

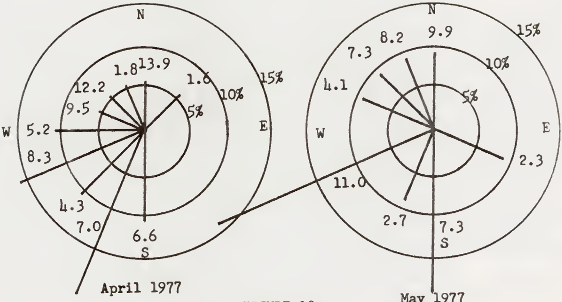
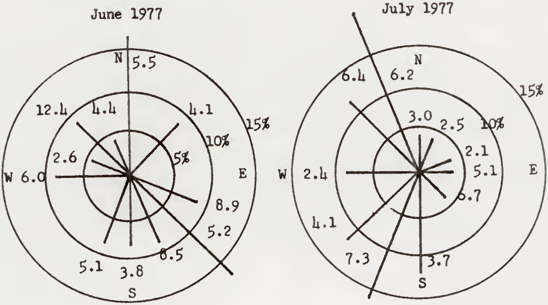


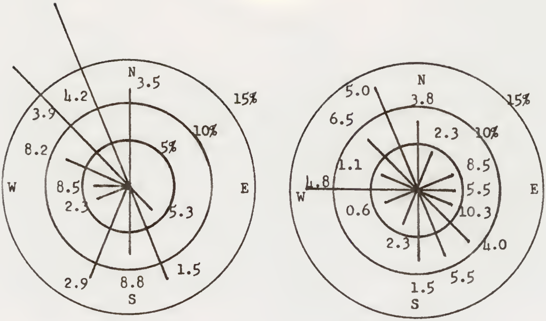
FIGURE 10

MONTHLY WIND ROSES

107 METER LEVEL

SCOBEY BORDER STATION, MONTANA





August 1977

September 1977

FIGURE 11

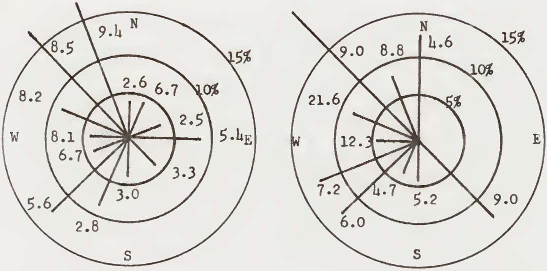
MONTHLY WIND ROSES

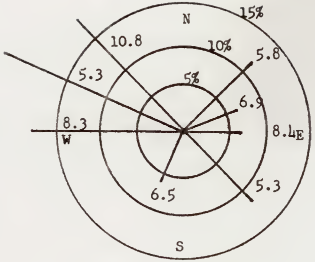
107 METER LEVEL

SCOBEY BORDER STATION, MONTANA

October 1977

November 1977





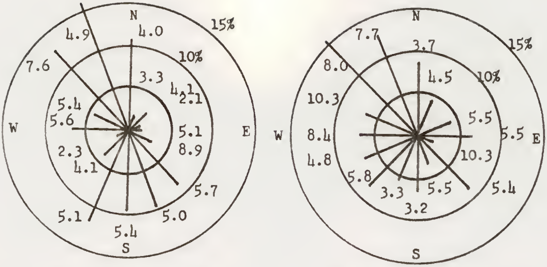
December 1977

FIGURE 12

MONTHLY WIND ROSES

107 METER LEVEL

SCOBEY BORDER STATION, MONTANA



Summer 1977 (Jun-Aug)

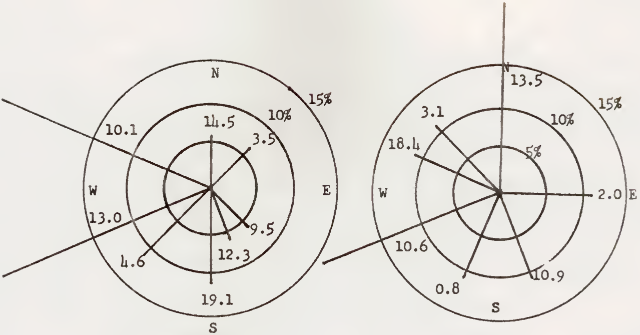
Autumn 1977 (Sep-Nov)

FIGURE 13

SEASONAL WIND ROSES

107 METER LEVEL

SCOBEY BORDER STATION, MONTANA



April 1977 May 1977

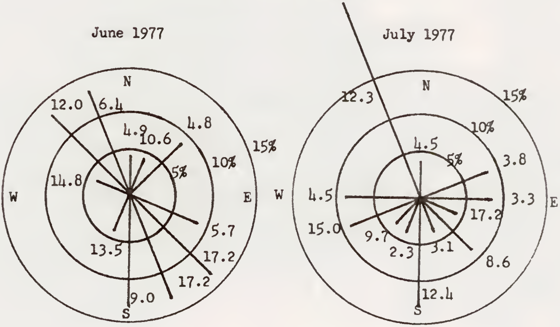
FIGURE 14

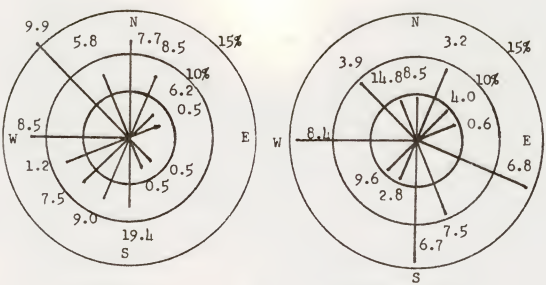
MONTHLY WIND ROSES

321 METER LEVEL

SCOBEY BORDER STATION, MONTANA

June 1977 July 1977





August 1977 September 1977

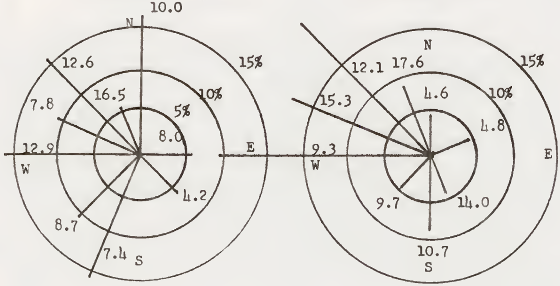
FIGURE 15

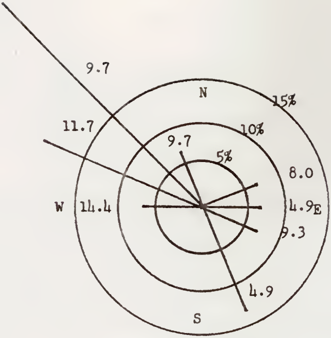
MONTHLY WIND ROSES

321 METER LEVEL

SCOBEY BORDER STATION, MONTANA

October 1977 November 1977





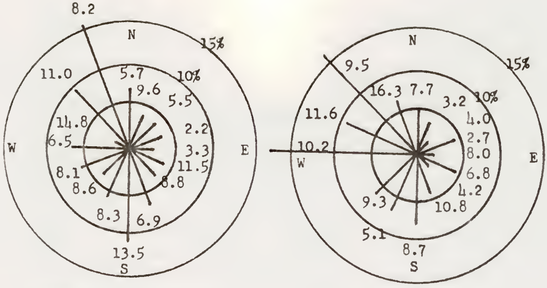
December 1977

FIGURE 16

MONTHLY WIND ROSES

321 METER LEVEL

SCOBEY BORDER STATION, MONTANA



Summer 1977 (Jun-Aug)

Autumn 1977 (Sep-Nov)

FIGURE 17
SEASONAL WIND ROSES

321 METER LEVEL

SCOBEY BORDER STATION, MONTANA

Table 9

BORDER STATION WIND ROSE 107m LEVEL

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Summer	Autumn
N	5.3	9.1	16.7	4.0	11.5	8.7	4.2	12.5	0	10.7	8.5
NNE	0	0	0	4.0	0	4.3	4.2	0	0	1.3	4.3
NE	5.3	0	8.3	0	0	0	0	0	11.8	2.8	0
ENE	5.3	0	0	4.0	0	4.3	4.2	0	5.9	1.3	4.3
E	0	0	0	4.0	0	4.3	8.3	0	5.9	1.3	6.3
ESE	0	9.1	8.3	0	0	4.3	0	0	0	2.8	1.4
SE	0	0	16.7	4.0	3.8	8.7	4.2	12.5	11.8	8.2	8.5
SSE	0	0	8.3	0	11.5	8.7	0	0	0	9.9	2.9
S	10.5	18.2	8.3	12.0	7.7	8.7	4.2	4.2	0	9.3	5.7
SSW	21.1	9.1	8.3	16.0	11.5	4.3	8.3	4.2	5.9	11.9	5.6
SW	10.5	0	0	12.0	0	0	0	12.5	0	4.0	8.3
WSW	15.8	27.3	0	0	3.8	4.3	4.2	12.5	0	1.3	7.0
W	10.5	0	8.3	8.0	3.8	13.0	4.2	4.2	17.6	6.7	7.1
WNW	5.3	9.1	4.2	0	7.7	4.3	8.3	8.3	23.5	4.0	7.0
NW	5.3	9.1	8.3	12.0	19.2	8.7	16.7	20.8	17.6	13.2	15.4
NNW	5.3	9.1	4.2	20.0	23.1	13.0	16.7	8.3	0	15.8	12.7

Values in percent

Table 10

BORDER STATION AVERAGE WIND SPEED 107m LEVEL

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Summer	Autumn
N	13.9	9.9	5.5	3.0	3.5	3.8	2.6	4.6		4.0	3.7
NNE			4.1	2.5		2.3	6.7			3.3	4.5
NE	1.6								5.8	4.1	
ENE	1.7			2.1		8.5	2.5		6.9	2.1	5.5
E				5.1		5.5	5.4		8.4	5.1	5.5
ESE		2.3	8.9			10.3				8.9	10.3
SE			5.2	6.7	5.3	4.0	3.3	9.0	5.3	5.7	5.4
SSE			8.5		1.5	5.5				5.0	5.5
S	6.6	7.3	3.8	3.7	8.8	1.5	3.0	5.2		5.4	3.2
SSW	7.0	2.7	5.1	7.3	2.9	2.3	2.8	4.7	6.5	5.1	3.3
SW	4.3			4.1			5.6	6.0		4.1	5.8
WSW	8.3	11.0			2.3	0.6	6.7	7.2		2.3	4.8
W	5.2		6.0	2.4	8.5	4.8	8.1	12.3	8.3	5.6	8.4
WNW	9.5	4.1	2.6		8.2	1.1	8.2	21.6	5.3	5.4	10.3
NW	12.2	7.3	12.4	6.4	3.9	6.5	8.5	9.0	10.8	7.6	8.0
NNW	1.8	8.2	4.4	6.2	4.2	5.0	9.4	8.8		4.9	7.7

Values in meters per second

Table 11

BORDER STATION WIND ROSE 321m LEVEL

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Summer	Autumn
N	5.6	22.2	4.3	4.2	11.5	4.8	15.8	4.3	0	6.7	5.0
NNE	0	0	4.3	0	7.7	9.5	0	0	0	4.0	3.2
NE	5.6	0	8.7	0	3.8	4.8	0	0	0	4.2	1.6
ENE	0	0	0	8.3	3.8	4.8	0	4.3	6.7	4.0	4.6
E	0	11.1	0	8.3	0	0	5.3	0	6.7	2.8	1.8
ESE	0	0	8.7	4.2	0	14.3	0	0	6.7	4.3	4.8
SE	5.6	0	13.0	8.3	3.8	0	5.3	0	0	4.0	1.8
SSE	5.6	11.1	13.0	4.2	3.8	9.5	0	4.3	13.3	7.0	4.6
S	11.1	0	13.0	12.5	7.7	14.3	0	8.7	0	11.1	7.7
SSW	0	11.1	4.3	4.2	7.7	4.8	15.8	0	0	5.4	6.9
SW	11.1	0	0	4.2	7.7	4.8	10.5	4.3	0	4.0	6.5
WSW	27.8	22.2	0	8.3	7.7	0	0	0	0	5.3	0
W	0	0	0	8.3	11.5	14.3	15.8	26.1	6.7	6.6	18.7
WNW	27.8	11.1	4.3	0	0	0	10.5	17.4	20.0	1.4	9.3
NW	0	11.1	13.0	0	15.4	9.5	15.8	21.7	33.3	9.5	15.7
NNW	0	0	13.0	25.0	7.7	4.8	5.3	8.7	6.7	15.2	6.3

Values in percent

Table 12

BORDER STATION AVERAGE WIND SPEED 321m LEVEL

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Summer	Autumn
N	14.5	13.5	4.9	4.5	7.7	8.5	10.0	4.6		5.7	7.7
NNE			10.6		8.5	3.2				9.6	3.2
NE	3.5		4.8		6.2	4.0				5.5	5.0
ENE				3.8	0.5	0.6		4.8	8.0	2.2	2.7
E		2.0		3.3			8.0		4.9	3.3	8.0
ESE			5.7	17.2		6.8			9.3	11.5	6.8
SE	9.5	5.9	17.2	8.6	0.5		4.2		4.9	8.8	4.2
SSE	12.3	10.9	17.2	3.1	0.5	7.5		14.0		6.9	10.8
S	19.1		9.0	12.4	19.4	6.7		10.7		13.5	8.7
SSW		0.8	13.5	2.3	9.0	2.8	7.4			8.3	5.1
SW	4.6			9.7	7.5	9.6	8.7	9.7		8.6	9.3
WSW	13.0	10.6		15.0	1.2					8.1	-
W				4.5	8.5	8.4	12.9	9.3	14.4	6.5	10.2
WNW	10.1	18.4	14.8				7.8	15.3	11.7	14.8	11.6
NW		3.1	12.0		9.9	3.9	12.6	12.1	9.7	11.0	9.5
NNW			6.4	12.3	5.8	14.8	16.5	17.6	9.7	8.2	16.3

Values in meters per second

Table 13

BORDER STATION MORNING MIXING HEIGHTS - NUMBER OF OCCURRENCES

1977

height (m)	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0-100	7	2	6	7	5	6	7	6	4
101-250	2	0	2	1	7	2	3	1	1
251-500	0	2	2	4	0	1	0	0	1
501-750	0	0	2	0	1	1	0	1	1
751-1000	0	0	1	0	0	1	1	1	1
1001-1500	0	0	0	0	0	0	0	0	0
>1500	1	1	0	0	0	0	1	2	0

Table 14

BORDER STATION MORNING MIXING HEIGHTS - PERCENT OCCURRENCE

1977

height (m)	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0-100	70.0	40.0	46.2	58.3	38.5	54.5	58.3	54.5	50.0
101-250	20.0	0.0	15.4	8.3	53.8	25.0	9.1	12.5	12.5
251-500	0.0	40.0	15.4	33.3	0.0	9.1	0.0	0.0	12.5
501-750	0.0	0.0	15.4	0.0	7.7	9.1	0.0	9.1	12.5
751-1000	0.0	0.0	7.7	0.0	0.0	9.1	8.3	9.1	12.5
1001-1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>5100	10.0	20.0	0.0	0.0	0.0	0.0	8.3	18.2	0.0

Table 15

BORDER STATION AFTERNOON MIXING HEIGHTS - NUMBER OF OCCURRENCES

1977

height (m)	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0-100	1	0	1	0	0	0	0	2	6
101-250	1	1	0	2	1	0	0	0	1
251-500	0	2	3	1	0	0	2	3	1
501-750	2	2	0	1	1	3	2	1	1
751-1000	0	0	1	0	0	1	0	1	0
1001-1500	0	0	3	1	5	2	4	1	0
>1500	5	1	3	8	7	6	4	5	0

Table 16

BORDER STATION AFTERNOON MIXING HEIGHTS - PERCENT OCCURRENCE

1977

height (m)	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0-100	11.1	0.0	9.1	0.0	0.0	0.0	0.0	15.4	66.7
101-250	11.1	16.7	0.0	15.4	7.1	0.0	0.0	0.0	11.1
251-500	0.0	33.3	27.3	7.7	0.0	0.0	16.7	23.1	11.1
501-750	22.2	33.3	0.0	7.7	7.1	25.0	16.7	7.7	11.1
751-1000	0.0	0.0	9.1	0.0	0.0	8.3	0.0	7.7	0.0
1001-1500	0.0	0.0	27.3	7.7	35.7	16.7	33.2	7.7	0.0
>1500	55.6	16.7	27.3	61.6	50.0	50.0	33.3	38.5	0.0

Table 17

BORDER STATION MORNING MIXING HEIGHTS

1977

Height (m)	Number of Occurrences Summer	Fall	Percent Occurrence Summer	Fall
0-100	18	19	47.4	55.9
101-250	10	6	26.3	17.6
251-500	6	1	15.8	2.9
501-750	3	2	7.9	5.9
751-1000	1	3	2.6	8.8
1001-1500	0	0	0.0	0.0
>1500	0	3	0.0	8.8

Table 18

BORDER STATION AFTERNOON MIXING HEIGHTS

1977

Height (m)	Number of Occurrences Summer	Fall	Percent Occurrence Summer	Fall
0-100	1	2	2.6	5.4
101-250	3	0	7.9	0.0
251-500	4	5	10.5	13.5
501-750	2	6	5.3	16.2
751-1000	1	2	2.6	5.4
1001-1500	9	7	23.7	18.9
>1500	18	15	47.4	40.5

Table 19

Glasgow, Montana
1971-1975

Seasonal Means of Daily Mixing Heights (m)

Spring		Summer		Fall		Winter	
Morn.	After.	Morn.	After.	Morn.	After.	Morn.	After.
133	305	203	1526	121	1995	168	1098

Table 20

Holzworth Inversion Classification Scheme

Class	$\Delta T/\Delta Z$ (C/100M)	Description
1	0.00 to +0.47	Weak Inversion
2	+0.48 to +1.14	Moderate Inversion
3	+1.15 to +2.82	Strong Inversion
4	+2.83 to +6.00	Very Strong Inversion
5	$> +6.00$	Extreme Inversion

Table 21

Inversion Study - Frequency of Occurrence Holzworth Classification
April - May 1977 Border Station (Morning)

						Inversion Base Height (m)						
Thickness (m)	SFc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100			2				2					4
101-250		1	1	2	1							5
251-500	8	1										9
Total	8	2	3	2	1		2					18
No. Inversions												1
Holz. Inv. Type												
1						1	2					3
2				1	1							2
3	3	2	3	1								9
4	5											5
5												0

Table 22

Inversion Study - Frequency of Occurrence Holzworth Classification
April - May 1977 Border Station (Afternoon)

						Inversion Base Height (m)					
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100	1		3	2	1		3	5	3	1		19
101-250						1		1	1		1	4
251-500					1			1				0
Total	1		3	2	2	1	3	7	4	1	1	25
No Inversions												3
Holz. Inv. Type												
1			1	1	2	1		3	2	1	1	12
2	1		1					3	1			6
3			1				2	1	1			5
4				1								1
5							1					1

Table 23

Inversion Study - Frequency of Occurrence Holzworth Classification
June, July and August 1977 Border Station (Morning)

					Inversion Base Height (m)							
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100	1	2	2	5	2	1	3	2		2		20
101-250	6	5	2	4	5	2	1	2	1			28
251-500	16	2		2	1	1						22
501-750												0
Total	23	9	4	11	8	4	4	4	1	2		70
No Inversions												1
Holz.Inv. Type												
1	1			4	4	4	4	3				20
2	5	3	3	5	3			1		1		21
3	12	4		2	1				1	1		21
4	5	2	1									8
5												0

Table 24

Inversion Study - Frequency of Occurrence Holzworth Classification
June, July and August 1977 Border Station (Afternoon)

		Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100		2	10	15	7	6	13	10	5	3		71
101-250				1		5	6	4	4			20
251-500				1			3	1				5
501-750												0
Total		2	10	17	7	11	22	15	9	3		96
No Inversions												3
Holz,Inv.Type												
1		1	2	8	3	6	11	9	7	2		49
2			2	5	1	4	9	5	2			28
3		1	5	3	3	1	2	1		1		17
4			1	1								2
5												0

Table 25

Inversion Study - Frequency of Occurrence Holzworth Classification
September, October and November 1977 Border Station (Morning)

	Inversion Base Height (m)											
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	> 3000	Total
1-100	4	3	3	8	2	2	8	4	1		1	36
101-250	9	3	4	1	3			1				21
251-500	6	1	1	1	1		1					11
501-750	1		1									2
Total	20	7	9	10	6	2	9	5	1		1	70
No Inversion												2
Holz.Inv. Type												
1		1		3	4	1	4	3	1			17
2			1	4	2	1	5	1			1	15
3	12	2	6	3				1				24
4	9	4	1									14
5												0

Table 26

Inversion Study - Frequency of Occurrence Holzworth Classification
September, October and November 1977 Border Station (Afternoon)

	Inversion Base Height (m)											
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100		1	2	2	8	6	10	8	6			43
101-250				3	2	1	4	2	2	1		15
261-500		2			1	2		2				7
501-750					1							1
Total		3	2	5	12	9	14	12	8	1		66
No Inversion												7
Holz, Inv. Type												
1			2	2	2	4	9	4	5	1		29
2		1		1	3	2	4	6	2			19
3		2		2	4	2	1	2	1			14
4					2	1						3
5					1							1

Table 27

Inversion Study - Frequency of Occurrance Holzworth Classification
December 1977 Border Station (Morning)

	Inversion Base Height (m)											
Thickness(m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100	1	1	3	3	3	1	2	1				15
101-250	3				1		1					5
251-500			1	1			1					3
501-750												0
Total	4	1	4	4	4	1	4	1				23
No Inversion												0
Holz.Inv. Type												
1				1	3		1	1				6
2			1	1		1	3					6
3	1	1	2	2	1							7
4	3		1									4
5												0

Table 28

Inversion Study - Frequency of Occurrence Holzworth Classification
December 1977 Border Station (Afternoon)

	Inversion Base Height (m)											
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	>3000	Total
1-100	3	1	2	5	2	1		3				17
101-250	1		2	3	2							8
251-500				1			1					2
501-750												0
Total	4	1	4	9	4	1	1	3				27
No Inversion												0
Holz Inv. Type												
1			1	5	1	1		2				10
2	1		2	1	2							6
3	3	1	1	2	1		1	1				10
4				1								1
5												0

Table 29

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Spring 1971 - 1975 (Morning)

			Inversion Base Height (m)								
Thickness (m)	Sfc	1-100	101-2500	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	4.1	0.2	0.2	0.0	0.2	0.2	0.7	0.7	0.0	0.0	6.3
101-250	20.4	0.8	2.0	1.9	2.3	0.4	0.6	0.4	1.4	0.4	30.5
251-500	31.0	0.4	1.3	1.7	2.2	0.6	0.8	0.2	0.2	0.2	38.7
501-750	5.9	0.0	1.8	0.2	0.6	0.0	0.6	0.2	0.2	0.0	9.6
> 750	1.9	0.4	2.5	0.8	0.6	0.0	0.2	0.2	0.2	0.0	7.0
Total	63.2	2.0	7.6	4.8	5.9	1.3	3.1	1.7	2.0	0.7	92.2
No Inversions											7.8
Holz. Inv. Type											
1	5.5	0.6	2.7	1.2	1.3	0.6	1.5	1.7	1.3	0.6	18.3
2	15.3	0.2	2.7	2.1	3.0	0.6	0.8	0.0	0.7	0.0	25.5
3	31.4	1.0	2.0	1.3	0.9	0.0	0.6	0.0	0.0	0.0	37.2
4	10.7	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 30

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Spring Season 1971 - 1975 (Afternoon)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-2500	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	0.8	0.2	0.2	0.4	0.8	0.2	1.8	2.1	0.2	2.2	9.1
101-250	2.1	0.0	0.4	1.3	1.8	1.1	3.5	5.4	4.4	4.6	24.7
251-500	1.1	0.4	0.4	1.6	2.4	0.4	3.3	3.3	1.8	0.4	15.0
501-750	0.4	0.2	0.2	0.6	1.5	0.7	1.1	0.0	0.2	0.2	5.2
>750	0.0	0.0	0.4	0.6	0.6	0.0	0.4	0.2	0.2	0.2	2.8
Total	4.6	0.9	1.7	4.6	7.2	2.4	10.0	11.1	6.8	7.6	57.0
No Inversions											48.0

Holz. Inv. Type											
1	1.7	0.2	0.6	1.9	2.4	0.4	4.7	6.0	3.7	4.1	25.9
2	0.8	0.4	0.6	2.0	3.3	1.6	2.8	3.0	2.9	1.7	19.0
3	1.3	0.0	0.4	0.6	1.4	0.4	2.2	2.0	0.2	1.8	10.6
4	0.6	0.2	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	1.3
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0

Table 31

Glasgow, Montana
Inversion Study - Frequency Percent Holzworth Classification
Summer 1971 - 1975 (Morning)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	4.9	0.0	0.2	0.4	0.0	0.0	0.0	0.0	0.0	0.4	6.0
101-250	24.1	0.4	1.3	1.4	0.8	0.4	0.6	0.8	1.1	0.2	31.2
251-500	42.9	0.4	1.0	0.4	0.4	0.6	0.4	0.6	0.0	0.4	47.5
501-750	7.0	0.2	0.9	0.6	0.0	0.0	0.0	0.0	0.0	0.0	8.8
>750	2.6	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8
Total	81.3	1.3	3.5	2.8	1.3	1.1	1.1	1.5	1.1	1.1	96.1
No Inversions											3.9
Holz. Inv. Type											
1	8.5	0.4	1.7	1.1	0.6	0.8	0.4	0.6	0.0	0.8	15.3
2	18.7	0.6	0.4	1.5	0.4	0.2	0.6	0.6	0.7	0.2	24.2
3	39.9	0.2	1.3	0.2	0.2	0.0	0.0	0.2	0.4	0.0	42.40
4	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
5	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1

Table 32

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Summer Season 1971 - 1975 (Afternoon)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-2500	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	0.9	0.0	0.0	0.2	0.4	0.0	1.5	1.5	0.4	0.8	6.0
101-250	0.6	0.0	0.2	0.0	0.2	0.2	1.3	3.7	5.5	6.2	18.0
251-500	0.0	0.0	0.0	0.2	0.0	0.4	0.9	2.0	1.5	2.4	7.5
501-750	0.0	0.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.7
> 750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2
Total	1.5	0.2	0.2	0.4	0.7	0.7	4.0	7.5	7.5	9.7	32.7
No Inversion											67.5
Holz. Inv. Type											
1	0.2	0.2	0.2	0.2	0.2	0.4	3.3	5.0	4.1	5.0	19.3
2	0.7	0.0	0.0	0.2	0.0	0.0	0.2	1.3	1.8	3.1	7.3
3	0.6	0.0	0.0	0.0	0.4	0.2	0.2	0.9	1.1	1.3	4.8
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.6
5	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.4

Table 33

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Fall Season 1971 - 1975 (Morning)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1=100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	4.0	0.0	0.4	0.0	0.4	0.2	0.8	0.0	0.0	0.0	5.9
101-250	18.0	0.2	0.4	1.0	2.3	0.8	0.6	0.4	0.9	0.0	24.9
251-500	34.1	0.6	0.6	0.8	3.9	1.3	0.4	0.7	0.0	0.0	41.6
501-750	10.4	0.2	1.5	1.8	0.4	0.2	0.4	0.0	0.0	0.2	15.2
>750	5.0	0.0	0.6	0.6	0.9	0.4	0.0	0.0	0.0	0.0	7.7
Total	71.4	1.1	3.7	4.4	6.8	3.1	2.4	1.1	0.9	0.2	95.2
No Inversions											4.8
Holz. Inv. Type											
1	5.3	0.2	0.8	1.7	2.7	0.4	0.6	0.7	0.2	0.2	13.1
2	15.9	0.0	1.0	1.7	2.6	1.7	0.4	0.2	0.7	0.0	24.4
3	31.0	0.4	1.7	0.6	1.6	0.4	0.8	0.2	0.0	0.0	36.9
4	18.9	0.4	0.0	0.2	0.0	0.4	0.4	0.0	0.0	0.0	20.5
5	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4

Table 34

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Fall Season 1971 - 1975 (Afternoon)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	2.8	0.0	0.4	0.6	0.4	0.0	1.5	1.3	0.0	1.1	8.4
101-250	5.7	0.4	0.6	1.2	4.4	2.0	5.9	4.0	4.6	1.7	30.8
251-500	3.7	0.2	0.8	1.8	1.0	2.1	1.9	1.8	1.8	1.5	16.6
501-750	0.9	0.0	0.6	0.9	0.8	1.3	1.1	0.4	0.4	0.4	7.0
>750	0.6	0.2	0.2	1.3	0.8	0.6	0.2	0.4	0.2	0.0	4.8
Total	13.9	0.9	2.9	5.5	7.7	6.2	10.8	7.9	7.0	4.8	67.6
No Inversion											32.4

Holz. Inv. Type											
1	4.6	0.6	1.2	3.1	2.9	3.0	5.9	4.2	3.3	3.9	33.2
2	4.2	0.2	0.8	0.6	3.0	1.9	2.8	2.0	2.4	0.4	18.8
3	4.5	0.0	0.4	1.0	1.1	1.1	1.7	1.5	1.3	0.2	13.2
4	0.4	0.0	0.2	0.6	0.4	0.0	0.2	0.2	0.0	0.2	2.4
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 35

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Winter Season 1971 - 1975 (Morning)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2501-3000	Total
1-100	0.4	0.0	0.0	0.4	0.2	0.0	0.4	0.0	0.0	0.0	1.5
101-250	10.3	0.2	1.3	0.4	1.3	0.6	0.0	0.4	0.2	0.2	15.2
251-500	30.1	0.8	2.8	1.2	0.6	1.1	0.0	0.0	0.0	0.0	37.9
501-750	12.4	1.3	1.0	2.7	0.8	0.2	0.0	0.0	0.0	0.0	18.6
>750	12.2	1.7	4.8	4.2	1.6	0.2	0.2	0.0	0.0	0.0	25.3
Total	65.6	4.2	10.2	10.0	4.9	2.2	0.7	0.4	0.2	0.0	98.7
No Inversions											1.3
Holz. Inv. Type											
1	6.4	0.6	0.8	0.6	1.7	0.4	0.0	0.4	0.0	0.2	11.4
2	14.8	1.3	5.1	4.5	1.2	1.3	0.0	0.0	0.2	0.0	28.8
3	28.8	1.7	3.2	4.0	1.2	0.2	0.6	0.0	0.0	0.0	40.0
4	14.8	0.4	0.8	0.8	0.4	0.2	0.0	0.0	0.0	0.0	17.7
5	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6

Table 36

Glasgow, Montana
Inversion Study - Percent Frequency Holzworth Classification
Winter Season 1971-1975 (Afternoon)

	Inversion Base Height (m)										
Thickness (m)	Sfc	1-100	101-2500	251-500	501-750	751-1000	1001-1500	1501-2000	2001-2500	2500-3000	Total
1-100	4.0	0.2	1.3	0.4	0.0	0.2	0.4	0.0	0.0	0.4	7.1
101-250	8.1	0.2	1.1	2.7	1.8	1.7	1.8	1.1	0.6	0.6	19.7
251-500	15.5	2.3	2.6	4.3	2.3	1.0	1.1	0.4	0.4	0.2	30.5
501-750	5.2	2.2	2.4	2.0	1.1	0.6	0.4	0.0	0.0	0.2	14.2
> 750	4.2	2.4	3.3	6.2	3.0	0.6	0.0	0.0	0.0	0.0	20.0
Total	36.8	7.5	10.9	15.7	8.2	4.4	3.8	1.6	1.1	1.6	91.5
No Inversion											8.4
Holz. Inv. Type											
1	6.30	1.0	3.20	3.50	1.30	1.00	1.80	1.10	0.40	0.6	21.30
2	8.60	2.6	2.90	6.20	2.60	1.40	0.90	0.20	0.40	0.4	28.10
3	16.00	2.7	4.00	5.10	4.10	1.50	0.60	0.20	0.20	0.20	37.00
4	5.40	1.0	0.60	0.80	0.20	0.20	0.20	0.0	0.0	0.0	8.60
5	0.70	0.0	0.00	0.00	0.0	0.00	0.20	0.0	0.0	0.00	0.70

III. VISIBILITY

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ABSTRACT

The construction of two 300 megawatt coal fired power plants at Coronach, Saskatchewan has caused great concern about the possible effects on Montana due to the close proximity of the plants. Visibility monitoring was one of the various background studies conducted during 1977 to allow an assessment of the power plants when operation begins. Measurements of visibility related parameters were made by two methods. These were a sun photometer and a solar irradiance system composed of a pyranometer and a pyrheliometer. Results are summarized along with problems encountered in the study. Recommendation is made for one additional year of background sampling with additional measurements of water vapor wavelengths and other necessary meteorological data.

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I. INTRODUCTION

On March 1, 1977, the Air Quality Bureau of the Montana Department of Health and Environmental Sciences initiated air quality related studies near the location for two proposed power plants in southern Saskatchewan. The power plants will be 300 megawatt coal-fired plants being built by Saskatchewan Power Corporation near Coronach, Saskatchewan. Concern was expressed by Montana residents over the possible effects of the plants being built so close to the Montana border (plants are located only 4 miles north of the border). Through funds made available by special appropriation of the U.S. Congress studies of various air and water effects were started or expanded during 1977. The Air Quality Bureau was given responsibility for six studies. These were background air quality monitoring, upper air meteorology, background visibility monitoring, coal analyses, soil sampling and vegetation chemistry.

This section will concentrate on one phase of the background study, that is visibility.

II. INSTRUMENTATION AND DATA COLLECTION

A. General Discussion

Visibility has become increasingly important in recent years. Recent federal Clean Air Act Amendments even mandate that the Environmental Protection Agency set down standards to protect the visibility. The amendments also set down certain areas as Class I areas where the air quality is to be kept as pristine as possible. These areas also will have to have the visibility protected. The nearest Class I area to Scobey is the Medicine Lake National Wildlife Refuge. This area consists of 11,366 acres some 60 miles SE of the Coronach power plants (Figure 1). The power plants proposed for the Poplar River area will have particulate collection devices that will capture 99.5% of the particulate emitted. However, the particulates captured are mainly the larger particles and the smaller particles will be transported downwind into Montana and other areas. The sub-micron particles have the greatest effect in obstructing the visibility.

For this reason, monitoring was conducted by various methods to establish a baseline of the visibility under various conditions. Various measurement methods were investigated prior to settling on two primary methods. It was suggested prior to the study to use photography or a laser. The photography method relies on distance large objects that could be photographed periodically. Through analysis of the contrast a measurement of the visibility is derived. The laser method also relies on distant objects and actually shoots a light beam at the object and measures the transmittance. The problem with both these methods for the Poplar River area was that no good distance objects were available to use. The area other than the small rolling hills has no large buttes or mountains. The highest point is the Four Buttes area but this is not visible from the Scobey Border Station area where the associated measurements were to be taken.

The two methods settled on for this background study were the use of a sun photometer and the use of a combination of measurements of direct beam solar insolation and total solar radiation. The following sections describe in more detail the instruments used and the theory behind the measurements.

B. Visibility Instrumentation

1. Photometer

Volz (1959) devised a simple instrument to determine turbidity B at 0.50 u. The instrument he described is the type used in this study. It consists of (1) an aperature plate with 3/16 inch diameter entrance hole which provides a viewing angle of 3.75°; (2) a Kodak Wratten 65 filter, band-pass 0.50 μ, peak transmission about 34%, and half-width about 0.067 μ; (3) a selenium photocell, sensitive from 0.30 to 0.68 μ; (4) a micrammeter; and (5) a diopter to measure the solar elevation angle; the diopter scale giving the optical air mass directly. The instrument was provided on loan by the Environmental Protection Agency (EPA).

The instrument is compact in size (2 by 2 by 5½ inches) and low cost. The Wratten 65 filter has an important secondary transmission beginning at about 0.70 μ and extending into the infrared, with a transmission near 75% at 0.78 μ. However, the selenium photocell is insensitive to radiation of wavelengths >0.68 μ, so that the small amount of radiation seen by the photocell outside the band-pass wavelength is insignificant. Output of the selenium photocells is nonlinear with intensity, but this feature is taken into account in the calibration of the sunphotometer.

Photometer observations were made whenever the line of sight to the sun was cloud-free. The readings were taken at 0900, 1200 and 1500 MST, if the operator was on site. With this restriction no extra trips to the site were required strictly for these measurements (round trip to the site was 28 miles).

The photometer performed reliably and the only problems that occurred were in the data analysis. First, the EPA provided a nomograph that was to be used to convert the meter readings to turbidity values. After some time of trying to use the graph, it was discovered that the graph was off scale. Conversion was then made to calculating values using the actual equations and doing it by computer. A second problem that occurred was that the instrument required surface pressure in the data reduction. The nearest pressure recording site was at Glasgow. This data was collected and used in the analysis. It is recommended that in the future, surface pressure be monitored on site if turbidity is to be recorded.

2. Pyranometer

An Eppley precision spectral pyranometer with a Schott WG 295 clear glass hemisphere was also operated continuously throughout the study at the Border Station site. The pyranometer provided a measure of radiation from wavelengths of 285 to 2800 mm. The pyranometer was calibrated at the factory previous to installation. The output from the pyranometer was recorded continuously on a Texas Instruments recorder. No problems occurred with the pyranometer. Periodic cleaning with distilled water of the hemisphere was required.

Frost also had to be scraped off on occasions. The only data loss occurred was when a lightning induced power surge damaged the recorder.

The pyranometer was installed on top of the hygrothermograph shelter some 25 feet from the trailer. The site was picked to be free from all overhead obstacles that could shadow the pyranometer.

3. Pyrheliometer

An Eppley normal incident pryheliometer for recording direct beam solar radiation was operated throughout the study at the Border Station site. The pyrheliometer was mounted on an Eppley solar tracker that automatically followed the sun throughout the day. The output from the pyrheliometer was recorded continuously on a Texas Instrument recorder. The same wavelength band as the pyranometer was used in the pyrheliometer.

The solar tracker had to be initially aligned to insure proper tracking on the sun by four settings. These were north to south, latitude, declination and time of day. After the initial alignment, the tracker only had minor corrections due mainly to changes in the sun declination. One problem that had to be dealt with was the output cord from the pyrheliometer. As the solar tracker turned around the cord would also wrap around the tracker base. Caution was to be taken to insure that this did not occur as the drive motor of the tracker could have been damaged. A cord holder was designed to hold the cord out away from the tracker and above the tracker. Then as the tracker turned the cord would slip through the holder but would not be allowed to wind around the tracker base. This system worked fairly well for about five days operation. At the end of that time the tracker was simply turned backward on its axis until the cord was unwound. This operation only took about a minute so little data was lost.

Another problem occurred when the recorder was damaged by the power surge discussed previously. Also some data was lost when a chart drive motor wore out. In very cold weather (less than -30C) the solar tracker operated slower than should be, causing some data loss.

The two solar radiation instruments, pyranometer and pyrheliometer, were used to relate to visibility. The analysis method is discussed in section IV.

C. Manpower

All of the instruments were operated by Mike Machler. The solar irradiance measurements were made continuously with the measurements being recorded on a strip chart recorder. The turbidity measurements were made at 0900, 1200, and 1500 MST if Mike Machler was on site during those times and if the weather conditions were right (sun not obscured). Any electronic problems that Machler could not handle were relayed to the Air Quality Bureau in Helena. Very few problems of this nature occurred.

D. Data Reduction and Analysis

All data measurements were reduced on site by Mike Machler. He recorded the values on computer forms and mailed both the forms and the strip charts to Helena on a monthly basis. The forms were then keypunched onto computer cards by the Department of Administration. The data was then analyzed by computer programs written by Jim Gelhaus specifically for this project. The programs produced monthly summaries of the data and calculated various statistics about the data.

III. SAMPLING RESULTS

A. Turbidity

1. Theory

Electromagnetic radiation from the sun has approximately the spectral content of a black body with temperature near 5900 K. Superimposed thereon are atomic and molecular emissions and absorptions. The majority (98%) of the solar spectral irradiance lies between 294 and 4000 nm. The most important spectral region is from 300 to 4000 nm for solar-thermal conversion systems and from 400 to 1100 nm for photovoltaic conversion.

The spectral energy density of the sun's radiation is nearly constant and is assumed as constant for this study. The principal effects at ground level are due to the rotation of the earth, the properties of the atmosphere, and to a much less extent, the earth-sun distance.

Scattering by air molecules (Rayleigh scattering) has a sizeable effect on the intensity of the direct solar irradiation at the shorter visible and ultraviolet wave lengths. The scattering coefficient is approximately proportional to the inverse fourth power of the wavelength. In the ultraviolet and the longer visible and infrared wavelengths, absorption by atmospheric gases is important.

Of the gases occurring naturally, the greatest effect on solar radiation is due to water vapor and ozone. Carbon dioxide, methane, nitrogen dioxide, and oxygen also play a role, but a relatively minor one in the normal atmosphere. However, man-made gaseous pollution and volcanic gases may result in significant absorption locally.

Let I_λ be the irradiance at wavelength λ at some observing point and I'_λ the irradiance at wavelength λ at some nearby observing point further from the sun; ΔX and σ will represent the separation between these two points and the extinction per unit length, respectively. If the distance between the two points becomes infinitesimal, then the relation is written:

$$- d I_\lambda = I_\lambda \sigma \ dx$$

The incremental extinction σdx may be rewritten $\sigma_m dM_h$ in terms of relative optical air mass M_h and the extinction per unit optical air mass σ_m. The relative optical air mass M_h is the amount of optical atmosphere between the sun and the observing point divided by the amount of optical atmosphere vertically above the observing point.

Extinction of sunlight is primarily due to ozone and water vapor absorption, and aerosol and molecular scattering. Expressed mathematically,

$$\sigma_m = B_\lambda + b_\lambda + k_\lambda$$

where B_λ, b_λ and k_λ are the aerosol scattering or turbidity coefficients as a function of wavelength per unit optical air mass, Rayleigh scattering of air molecules per unit optical air mass, and absorption by the ozone layer or water vapor per unit optical air mass, respectively. Incorporating this relation:

$$- d I_\lambda / I_\lambda = (B_\lambda + b_\lambda + k_\lambda) \ dM_h$$

Integrating this relation from the earth's surface to the top of the atmosphere we obtain:

$$I \quad = (I_o \;\; /S\ e\ (B_o \;\; +b \;\; +k)\ M_h$$ Malm(1977).

where $I_{o\,\lambda}$ is the extraterrestrial irradiance of wavelength λ at the mean sunearth distance, and S a correction factor for the mean sun-earth distance. Because most of the ozone of the atmosphere is above the observing point, regardless of its elevation above sea level, no height or pressure correction is necessary for k_λ specifically for ozone. Background atmospheric aerosol concentrations depend on attitute. However, often local aerosol contributions (aerosol due to wind blown dust, pollutants from stationary and mobile sources, etc.) tend to dominate the turbidity coefficient and B_λ is consequently usually assumed to be altitute independent. The attenuation due to Rayleigh scattering could have been corrected for altitute by multiplying by the ratio of p/p_o where p is the station pressure and p_o is the standard pressure at sea level. However, the correction used here was to take values from Elterman (1968).

Water vapor absorption does play an important role in affecting the turbidity measured. However, the sun photometer used in this study consisted only of two channels (380 and 500 nm). No relation could be made as to the effect of the water vapor, only correlations of surface relative humidities or synoptic air masses could be made. The water vapor band is centered at 940 nm. It is recommended that additional channels be measured to derive the effect of the water vapor.

In order to be able to compare I_λ with previous measurements of other studies, the equation must be changed from the natural logarithm to the base 10 logarithm. The basic equation then becomes:

$$I_\lambda = (I_{o\lambda}/S)\ 10 \exp\ (B_\lambda + k_\lambda + b_\lambda (P/P_o)\ M_h$$

Solving this equation for the turbidity coefficient gives:

$$B_\lambda = (\mathrm{Log}\ (I_{o\lambda}/I_\lambda S))/M_h - b_{h\lambda} - k_\lambda$$

where $b_{h\lambda}$ is the scattering due to air molecules at height h. The resulting base 10 absorption and extinction coefficients per optical air mass are 0.434 times the base e absorption and extinction coefficients. (Malm, 1977).

The sunphotometer does not measure the actual irradiance but rather it provides a meter deflection J_λ in microamperes which is directly proportional to I_λ. Similarly, $J_{o\lambda}$, which is the instrument calibration factor, is the meter reading when the irradiance is $I_{o\lambda}$. The diopter scale on the sunphotometer provides values of the relative optical air mass, M_h.

However, the relative optical air mass was calculated in this case by the following set of equations:

$$m = \sec \theta_o \text{ for zenith angles 0 to } 60^\circ$$

$$m = \sec \theta_o - 3.93 \times 10^{-4} \sec \theta_o^{3.65}\ p/p_o$$

$$\text{for } \sec \theta_o > 1.5$$

$$m = \sec \theta_o - 8.61 \times 10^{-4} \sec \theta_o^{2.69}\ p/p_o$$

$$\text{for } 1.5 < \sec \theta_o < 15.0$$

where p= site pressure and p_o = sea level pressure, and θ_o = solar zenith angle (Hullstrom, 1977). The solar zenith angle may be calculated by the equation:

$$\cos \theta_o = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t$$

where: ϕ = latitute of site (49° 00' for Border Station Site)

δ = solar declination for that day

t = solar hour angle (angle between apparent noon and time of observation)

Solar hour angle = (true solar noon (MST) -
12:00 MST + longitude correction -
equation of time for date) x 15°/hour

longitute correction = (site longitude - standard meridian (105 deg W) of mountain time zone) x 4 min/deg. longitude.

The value obtained should be positive if the site is west of the meridian and negative if east. The longitude of the Border Station site is 105° 25' W. Therefore the correction is + 1 min. 40 sec.

The equation of time is obtained from standard astronomical tables (World Almanac, 1977) and varies from - 14 1/3 to + 16 1/3 minutes.

The solar declination is also obtained from similar tables (Nautical Almanac, 1977) from - 23½ deg. on Dec. 21 to + 23½ deg. on June 21.

2. Previous Studies

Flowers et al. (1969) found that Missoula, Montana had an annual turbidity of 0.08 while Idaho Falls, Idaho had a value of 0.05 using a 500 nm wavelength. The pollution sources and meteorology of these two closest sites to Scobey are much different than the Scobey area. The Scobey area is very much agricultural with no mountainous terrain whereas Missoula especially has various point sources of air pollution and high mountainous terrain on all sides. Huron, South Dakota, is probably the most similar site to the Scobey area of these areas studied by Flowers. Flowers showed an annual turbidity for Huron of 0.07. The seasonal distribution for Huron showed a peak in mid-summer (as high as 0.10) with minimum values in the winter (as low as 0.04). The Idaho Falls distribution showed a similar pattern but the peak was only 0.07. Flowers also demonstrated that various synoptic air masses showed differing values of turbidity. Polar continental air masses were less turbid than tropical maritime air masses. Investigations of the Huron, SD data showed that turbidity was lowest following a cold frontal passage and gradually increased until the next frontal passage. Lower turbidities were observed almost always when polar or artic air replaces tropical air. These findings indicate that either the cold air masses carried less particles or that the tropical air with the higher humidities had larger particles due to growth of the particles from water vapor. Rainfall was also shown to have little effect on the turbidity values. Rainfall has been shown to cleanse dust particles from the air but the Flowers data demonstrates that the rain makes little change in the turbidity values.

A very sophisticated short-term study was also carried out near Colstrip, Montana (Lerfald, 1977) to improve data on the individual atmospheric components which cause the absorption and scattering of solar radiation. Various instruments and techniques were employed including the use of a two channel Volz sun photometer (382 and 502 nm).

Measurements were made during August and December, 1975. The nearby power plant (Colstrip Unit No. 1) started commercial operation about October, 1975. Using the 502 nm channel, the August results showed values in the range of 0.03 to 0.13 with an average of approximately 0.07. The results also showed a probable effect of thermal plumes lifting local dust into the atmosphere during the morning hours. This effect was attributed to the solar heating rather than the nearby strip mines. The results also showed a diurnal pattern of increasing decadic extinction or turbidity during the morning until noon where the peak leveled off and gradually decreased during the afternoon.

A similar study of optical attenuation was conducted near Stanton, North Dakota by Martin Marietta Copporation (Hullstrom, 1977). The study was conducted several week periods during the spring, summer, fall and winter of 1976 - 77. Measurements were made with a five channel Volz sun photometer for various cloud conditions. However, all measurements were made when the sun was not visibly obscured by clouds. Using the five channels (380, 440, 500, 640 and 880 nm) one could subtract out the effect of water vapor and ozone absorption and obtain the attentuation due to atmospheric aerosol only. Comparing could free conditions for April, 1976 at the 500 nm wavelength, the total attenuation (with water vapor and ozone absorption included) averages about 0.28 (using base e formula). With water vapor and ozone absorption subtracted out, the average value becomes about 0.12 (again using base e, multiply by 0.434 to convert to base 10).

With clouds present these values are about 0.35 and 0.22, respectively. This difference between cloud-free and cloud-present conditions is explained by Hullstrom as being due to high thin cirrus clouds. For the summer season, the results were very similar as the spring season. The fall season showed values much less than either spring or summer. Also the difference between total and aerosol attenuation was less indicating less water vapor present in the fall. The winter season showed similar total attenuation values as the fall season but the aerosol attenuation values were very small, on the order of 0.03.

Angstrom's (1929) wavelength exponent, α may be calculated from the turbidity coefficient as the two wavelengths as follows:

$$\alpha = \frac{\operatorname{Ln} \frac{B(380)}{B(500)}}{\operatorname{Ln} \frac{500}{380}}$$

The wavelength exponent is related to the γ exponent in the Junge (1961) particle size distribution equation by $\alpha = \gamma - 2$ so that α thus becomes an indicator of the relative abundance of large and small particles within the limited size spectrum from $0.1\ u < r < 1.0\ u$. The exponent may vary between 0 and 4 but generally it is within the range from 0.5 to 2.5 and has a mean of 1.3. An α value of 0.5 would indicate a greater than average proporation of large particles while an α value of 2.5 would indicate a lesser than average proporation of large particles.

The problem with the wavelength exponent is when water vapor absorption is not taken into account B (380 nm) can be less than B (500 nm) causing the logrithm to be negative. The problem was also noted by Malm (1977).

Using the results of Malm (1977) the wavelength exponents for the 380 and 500 nm wavelengths were calculated. The results showed values from approximately 1.0 in the summer to 2.5 in the winter with the value for all measurements at approximately 1.6. Using Hullstrom (1977), values such as 0.8 in the spring and 1.2 in the fall were calculated. However, these values were after the water vapor and ozone absorption had been subtracted out. Using the total attenuation these values were 2.6 and 3.1, respectively.

3. Turbidity Results

The turbidity measurements are summarized in tables 1 through 4. In caluclating the relative air mass for these tables,one problem was encountered. This was the site pressure was needed for the calculation. No pressure measurements were being made on-site. Reliance had to be made on pressure measurements at Glasgow some 70 miles away. In the future a recommendation will be made to have on site pressure. With this in mind Table 1 summarizes the turbidity measurements for the two wavelengths (380 and 550 nm) for the months of 1977. The summary also shows the averages etc. for the seasons and annual period. The results show a gradual peak of highest readings in May and June with the lowest readings in November. No readings were available for January or February. The seasonal trend shows the same pattern with the highest average in summer and lowest in winter. The winter average contains only one month of data. The two wavelengths show the same trend with the 380 nm resulting in consistently higher levels by about 0.01. If one compares these results to previous studies, Flowers et al. (1969) found an average of 0.08 in Missoula using 500 nm wavelength.

This and other comparisons are shown in table 2. The Poplar River data shows the lowest annual turbidity. The Stanton, N.D., results presented by Hullstrom are also very similar if one converts them to the base 10 logrithm. The trend is similar to that measured in Huron, SD, with the high in mid-summer and the low in winter. Comparing the Poplar River results with monthly precipitation amounts (Fig.2&3) shows very little correlation. This lack of effect was noted previously by Flowers.

Table 1 also shows the wavelength exponents as defined by Ånström (1929). The value varies from near zero to 1.1. One negative average was shown as were various individual readings noted. This effect was probably due to the interference of water vapor. The results are much lower than that noted by Hullstrom (1977) for Stanton, ND. The results would seem to indicate a large abundance of large particles as would be expected for this area. No significant industrial sources are located here to produce the small particles. The wind blown dust from the fields would be expected to be large particles.

Table 3 shows the turbidity results averaged by season for the hours when the surface wind was blowing from the WNW through N or transboundary flow. This criteria is based partially on the Glasgow surface data as the wind system at Scobey was damaged for the summer months. The results show no surprising differences from previous summaries other than the winter results. The winter results are much higher than previously reported. This could be due to a small sample (only December data) or to the fact that winter is the best season for good visibility. More data will determine which is true.

Table 4 shows the monthly turbidity results averaged by the time of day that the observation was taken. The results again are presented for both the 380 and 500 nm wavelength. The results don't show any real trend as far as the time of day. Looking at the results on season or annual averages, there still appears no trend.

B. Solar Irradiance

1. Theory

Using the theory from the turbidity section, a second measurement technique was employed called solar irradiance. The normal incident direct solar irradiance, I, the diffuse sky irradiance, S, and the total solar irradiance on a horizontal surface, H, are related by the following equation:

$$H = I \cos \theta + S$$

Where θ is the solar zenith angle. The normal incident direct solar irradiance can be related to the atmospheric transmittance, T, by

$$I = I_o \; T$$

where I_o is the extraterrestrial solar irradiance (solar constant). Atmospheric transmittance can be given by

$$T = \exp\left(-\sigma_m \; M_h\right)$$

where σ_m is the vertical optical depth of the atmosphere, and M_h is the relative air mass. The total optical depth is a function of wavelength, λ , and the scattering characteristics of atmospheric particulates, molecules, and the absorption by atmospheric constituents such as water vapor, carbon dioxide, etc. In general, the total atmospheric optical depth can be given by

$$\tau_m = B_\lambda + b_\lambda + k_\lambda$$

where B_λ , b_λ and k_λ are the aerosol scattering or turbidity coefficients as a function of wavelength per unit optical air mass; Rayleigh scattering of air molecules per unit optical air mass; and absorption by the ozone layer or water vapor per unit optical air mass, respectively. The visible region (0.3 - 0.7 um) is dominated by attenuation due to molecular and particulate scattering, and the near infrared (0.7 - 2.8 um) region is dominated by attenuation due to absorption by water vapor (Lerfald, 1977).

The normal incident direct solar irradiance was measured continuously with one Eppley pyrheliometer. This unit was unfiltered and monitored the direct solar beam in the 0.3 to 2.8 um region. Had more funds been available, one additional pyrheliometer with a RG-8 filter (0.68 to 2 um) could have allowed the subtraction of most of the attenuation due to water vapor absorption. Similarly with the Eppley pyranometer used, only one unfiltered unit was operated causing the same problem. The analysis of the solar irradiance consisted of determining the atmospheric optical depth, the ratio of diffuse to total solar irradiance and the relationship between the direct irradiance and the total irradiance all for the total spectrum (0.3 to 2.8 um).

The optical depth or decadic extinction was calculated by

$$\sigma_m = \frac{\ln I/I_o}{M_h}$$

where the value for I_o was taken to be 1.94 cal/cm^2 at the mean sun-earth distance. This value was adjusted for the particular sun-earth distance existing at the time (day) that I was measured. The solar zenith angle was calculated by conventional equations. The ratio of diffuse, S, to total, H, solar irradiance was obtained from measurements of each parameter.

2. Previous Studies

Previous measurements of the total spectrum have been both in Boulder, Colorado (Lerfald, 1977) and Stanton, North Dakota (Hullstrom, 1977). At Boulder, Colorado, brief measurement periods were made on August 7, 1976, and December 9, 1976. The actual data collection periods were too short for comparison here. However, several conclusions drawn from the results are of importance here. (1) Broadband (285 to 2800 nm) solar irradiance and atmospheric attenuation can vary markedly from hour-to-hour and from day-to-day; these variations are caused by changes in the atmospheric particulate and water vapor content. (2) For conditions approaching a clear, dry, molecular atmosphere (at 1.61 Km above sea level) the optical depth was measured to be 0.177 to 0.128 for the 285 to 2800 nm region (base e logrithm), corresponding to a vertical transmittance (air mass of one) of 84 to 88%. (3) Cirrus clouds, as measured in this study, are quite transparent to solar irradiance, having a vertical transmittance of 78 to 99%, which is fairly independent of wavelength

(Lerfald, 1977).

The Stanton, North Dakota, results demonstrated that January had the clearest conditions followed by October, July, and April. Further analyses showed that the slope of plot of the ratio of diffuse to total solar irradiance versus relative air mass is directly proportional to the broadband optical attenuation coefficient. By considering the slope of such plots, the variable impact of the ground albedo on diffuse irradiance was eliminated. An analysis of the total solar irradiance versus relative air mass revealed that for the months of April, July, and October, the total solar irradiance versus relative air mass is a constant relationship, despite a wide range of atmospheric conditions of haze and clouds. This indicates that when the direct solar beam is attenuated, the diffuse sky irradiance increases an amount which compensates for the loss in direct solar irradiance. January had a slightly different total solar irradiance versus relative air mass because of the influence of snow cover and cirrus clouds which resulted in greater amounts of total irradiance for a given relative air mass. The following are the results of a comparison of seasonal slopes of diffuse to total ratio versus relative air mass (Hullstrom, 1977).

Month	Slope
April	0.060
July	0.048
October	0.038
January	0.026

3. Solar Irradiance Results

The solar irradiance results are summarized in tables 6 through 8. Table 6 summarizes the minimum,maximum and average readings by month and season of the incident solar radiation, the direct solar beam irradiance, the diffuse solar irradiance and the ratio of the diffuse to the total irradiance. Table 6 also shows the average relative air mass by month and season.

Looking just at the incident solar radiation, the trend is toward very low readings in the winter and late fall and highest readings in the mid-summer. This would be expected for this latitude. The breakdown by season shows the same results. The average reading over the ten month period was 0.24 langleys per minute.

The direct solar beam measurements show fairly constant readings for all months of the year except December. For the months other than December the readings average about 0.30 langleys per minute. However for December the average drops to 0.06. The average of the ten months was 0.26 langleys per minute.

The diffuse solar irradiance shows a trend similar to that of the incident solar radiation. The values are, however, much lower averaging 0.10 langlyes per minute for the ten months. This relationship would be expected due to the primary equation described in paragraph one of the theory.

The ratio of the diffuse to the total solar irradiance shows a very constant figure of about 0.34 for all the months. Each season also shows a very similar value. Even the maximum values for each month vary very little.

The results indicate that the late fall and early winter were the clearest while early summer had the most obstructed visibility. These results compare favorably with those obtained by Hullstrom (1977) at Stanton, ND. The results do not show any clear correlation with precipitation amounts for the various months (table 5).

Table 7 shows the ratio of the diffuse to the total solar irradiance separated by hours with clear conditions versus hours with percent total cloud cover one tenth or greater. This allowed the development of two baselines, one for cloud free conditions and one for clouds present conditions. The major problem with the separation was that the could conditions had to be derived from observations taken at Glasgow some 70 miles away. There was no method available to obtain this information on site. However, it was felt that the synoptic situation would be similar enough to give Glasgow and Scobey the same general cloud cover.

The results for cloud free conditions showed very low averages with the overall average being only 0.12. The corresponding air mass was only 0.99. There was no clear trend however the early summer again had the highest readings. December which was the clearest month of those monitored now had a fairly high cloud free reading. This may be due to the extreme cold causing ice crystals to be present in the atmosphere.

The clouds present results showed much higher readings than the cloud free conditions. The average for the ten months was 0.39 with a corresponding air mass of 1.82. There was no real clearer month although the late fall and early winter season did average slightly lower than the remainder of the year. The seasonal analysis showed the winter (December only) as the clearest and summer as the most obstructed visibility.

Table 8 shows a second method of attempting to establish a baseline under two conditions. The conditions chosen were (1) when the direct beam solar irradiance was greater than 1.0 and (2) when the direct beam solar irradiance was less than 1.0. The results for the two ratios appear very similar to the results presented in table 7. However the relative air masses are much higher for the hours when the ratio is greater than one. It is recommended that if monitoring is continued that several different methods are attempted to allow baselines to be established under different conditions. Since cloud cover presents a problem, possibly baselines can be established for various stability classes.

IV. SUMMARY AND RECOMMENDATIONS

Turbidity and solar irradiance readings were taken for a ten month period from March to December. Despite problems with obtaining on site pressure and cloud cover, very good data was obtained throughout the period. The results showed the early summer as the most turbid and the late fall and winter as the clearest. Precipitation appeared to have no direct effect on the results. The results appeared very similar to previous results obtained in North Dakota and Colstrip. Baselines for transboundary flow and cloud free versus cloud present conditions were developed.

Recommendations are made for an additional year background sampling by both methods. Additional measurements of water vapor wavelength band and on site pressure are recommended. Also a baseline should be established for levels during the various stabilities. Baselines should also be established for upper level transboundary wind flow, synoptic weather patterns, crop stage and wind speeds.

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APPENDIX

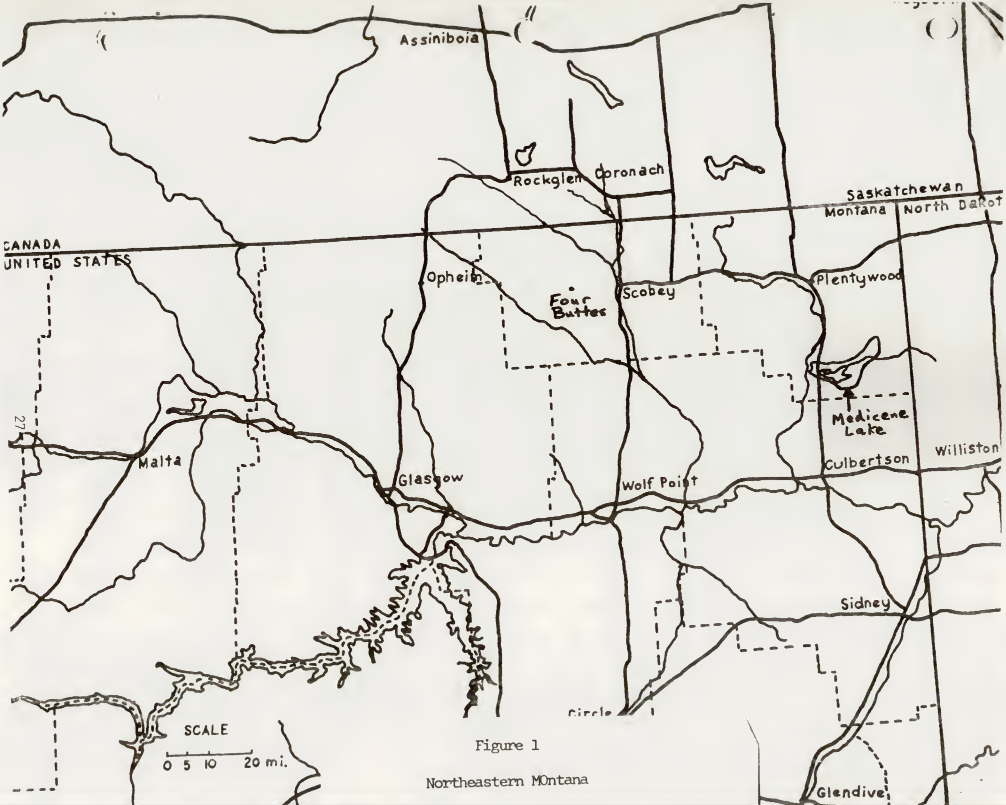

Figure 1

Northeastern MOntana

Table 1

Poplar River Atmospheric Turbidity Data
1977

Month	380 nm Aver	Min	Max	500 nm Aver	Min	Max	No. Samples	Wavelength Exponent	Relative Air Mass
March	0.04	0.02	0.10	0.04	0.02	0.11	13	0.259	2.12
April	0.06	0.04	0.17	0.06	0.04	0.15	23	− 0.146	1.54
May	0.08	0.05	0.17	0.07	0.05	0.14	15	0.529	1.32
June	0.08	0.04	0.14	0.06	0.04	0.11	25	0.800	1.29
July	0.07	0.04	0.12	0.06	0.04	0.09	25	0.541	1.31
August	0.07	0.01	0.16	0.06	0.02	0.14	23	0.062	1.45
September	0.04	0.01	0.07	0.04	0.02	0.06	13	0.175	1.74
October	0.05	0.01	0.14	0.04	0.01	0.10	21	0.716	2.50
November	0.02	0.00	0.06	0.02	0.01	0.05	23	0.788	4.12
December	0.03	0.01	0.07	0.02	0.00	0.06	8	1.132	5.14
Spring	0.06	0.02	0.17	0.06	0.02	0.15	51	---	1.62
Summer	0.07	0.01	0.16	0.06	0.02	0.14	73	---	1.35
Fall	0.04	0.00	0.14	0.03	0.01	0.10	57	---	2.98
Winter*	0.03	0.01	0.07	0.02	0.00	0.06	8	---	5.4*
Annual+	0.057	0.00	0.17	0.049	0.00	0.15	189	---	2.07

* December only
+ Ten months

Table 2

Annual Average Turbidities+ 500 nm Wavelength

Site	Average
Poplar River, MT	0.05
Missoula, MT	0.08
Idaho Falls, ID.	0.05
Huron, SD	0.07
Colstrip, MT	0.07*

* one month only

+ all results given here in base 10.

Figure 2
Comparison of Turbidity Versus Precipitation
as Measured in the Poplar River Area During 1977

λ = 500 nm

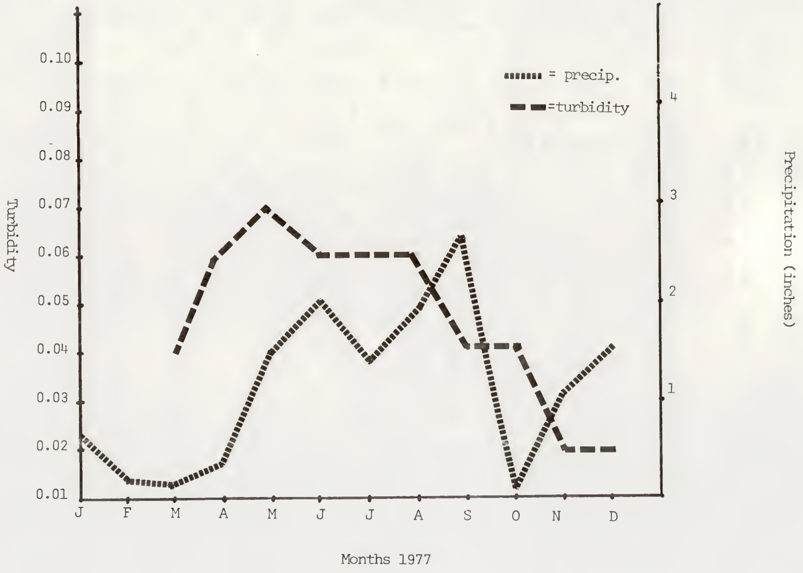

Figure 3

Comparison of Turbidity Versus Precipitation
as Measured in the Poplar River Area During 1977

$\lambda = 380$ nm

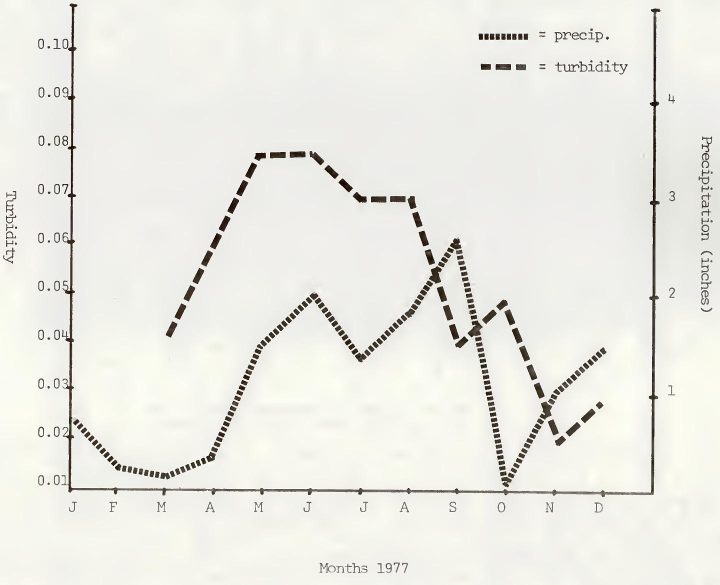

Table 3

Poplar River Atmospheric Turbidity Data
Hours When Surface Wind Blowing From WNW - N

	Aver. 380 nm			Aver. 500 nm		
Month	0900	1200	1200(MST)	0900	1200	1500(MST)
Spring	0.043	0.048	0.043	0.038	0.046	0.040
Summer	0.071	0.070	0.073	0.057	0.062	0.064
Fall	0.030	0.052	0.040	0.020	0.042	0.030
Winter*	0.070	0.050	0.060	0.060	0.040	0.040
Annual	0.060	0.057	0.060	0.049	0.050	0.052

* one reading only as December, 1977, data only available.

Table 4

Poplar River Atmospheric Turbidity Data
Daily Trends
1977-78

	Aver 380 nm			Aver 500 nm		
Month	0900	1200	1500 (MST)	0900	1200	1500 (MST)
March	0.040	0.040	0.052	0.035	0.033	0.050
April	0.064	0.058	0.060	0.064	0.062	0.066
May	0.055	0.098	0.073	0.055	0.078	0.064
June	0.083	0.073	0.069	0.063	0.059	0.057=
July	0.061	0.071	0.068	0.051	0.060	0.058
August	0.079	0.062	0.069	0.068	0.058	0.064
September	0.038	0.042	0.042	0.032	0.040	0.038
October	0.048	0.053	0.053	0.036	0.044	0.038
November	0.018	0.022	0.020	0.011	0.018	0.013
December	0.055	0.027	0.027	0.040	0.020	0.017
Spring	0.054	0.069	0.063	0.052	0.062	0.062
Summer	0.075	0.069	0.069	0.061	0.059	0.060
Fall	0.032	0.040	0.037	0.023	0.034	0.028
Winter *	0.055	0.027	0.027	0.040	0.020	0.017
Annual +	0.057	0.057	0.056	0.047	0.049	0.050

* only one month of data

+ only ten months of data

Table 5
Monthly Total Precipitation
Scobey - 1977

Month	Total (inches)	Departure from Normal (inches)
January	0.72	0.14
February	0.22	-0.28
March	0.12	-0.48
April	0.36	-0.63
May	1.54	-0.13
June	2.06	-0.98
July	1.35	-0.37
August	1.83	0.97
September	2.68	1.46
October	0.05	-0.57
November	1.08	0.66
December	1.56	1.06
Year	13.57	-0.05

Table 6
Poplar River Solar Irradiance Data +

	Incident Solar Rad.			Direct Solar Beam			Diffuse Irr.			Ratios Diffuse to Total			Relative Air Mass
Month	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Min	Max	Aver	Aver
March	0.0	1.10	0.22	0.0	1.39	0.25	0.0	0.59	0.10	0.0	1.23	0.33	1.61
April	0.0	1.21	0.32	0.0	1.37	0.35	0.0	0.89	0.12	0.0	1.65	0.32	1.57
May	0.0	1.31	0.33	0.0	1.37	0.30	0.0	0.67	0.14	0.0	2.08	0.40	1.94
June	0.0	1.33	0.37	0.0	1.34	0.33	0.0	0.85	0.15	0.0	1.06	0.39	1.54
July	0.0	1.31	0.38	0.0	1.35	0.38	0.0	0.68	0.13	0.0	1.34	0.34	1.75
August	0.0	1.18	0.27	0.0	1.34	0.36	0.0	0.65	0.12	0.0	1.97	0.36	1.64
September	0.0	1.04	0.18	0.0	1.30	0.17	0.0	0.56	0.08	0.0	1.82	0.37	1.66
October	0.0	0.86	0.15	0.0	1.31	0.23	0.0	0.49	0.06	0.0	1.54	0.29	1.68
November	0.0	0.63	0.10	0.0	1.31	0.20	0.0	0.35	0.04	0.0	1.95	0.27	1.71
December	0.0	0.53	0.06	0.0	1.12	0.06	0.0	0.33	0.05	0.0	1.41	0.31	1.50
Spring	0.0	1.31	0.29	0.0	1.39	0.30	0.0	0.89	0.12	0.0	2.08	0.35	1.71
Summer	0.0	1.33	0.34	0.0	1.35	0.36	0.0	0.85	0.13	0.0	1.97	0.36	1.64
Fall	0.0	1.04	0.14	0.0	1.31	0.20	0.0	0.56	0.06	0.0	1.95	0.31	1.68
Winter *	0.0	0.53	0.06	0.0	1.12	0.06	0.0	0.33	0.05	0.0	1.41	0.31	1.50
Annual	0.0	1.33	0.24	0.0	1.39	0.26	0.0	0.89	0.10	0.0	2.08	0.34	1.66

* December only

+ Values in langleys/min for S, H and I

Table 7
Poplar River Ratio of Diffuse to Total Solar Irradiance
Method 1

	Aver. Cloud Free Conditions		Aver Clouds Present Conditions	
Month	S/H	Air Mass	S/H	Air Mass
March	0.11	0.63	0.39	1.86
April	0.15	1.08	0.41	1.81
May	0.18	0.94	0.42	2.06
June	0.13	1.15	0.44	1.63
July	0.09	1.29	0.38	1.84
August	0.11	1.27	0.48	1.75
September	0.11	0.83	0.43	1.79
October	0.12	1.23	0.33	1.83
November	0.09	0.87	0.33	1.99
December	0.16	0.65	0.32	1.61
Spring	0.15	0.88	0.41	1.91
Summer	0.11	1.24	0.43	1.74
Fall	0.11	0.98	0.36	1.87
Winter *	0.16	0.65	0.32	1.61
Annual	0.12	0.99	0.39	1.82

* December only

Table 8
Poplar River Ratio of Diffuse to Total Solar Irradiance
Method 2

Month	Direct Beam >1.0		Direct Beam <1.0	
	S/H	Air Mass	S/H	Air Mass
March	0.18	1.98	0.35	1.53
April	0.16	1.58	0.36	1.57
May	0.13	1.43	0.45	1.85
June	0.10	1.40	0.44	1.57
July	0.10	1.46	0.39	1.81
August	0.11	1.72	0.41	1.77
September	0.09	1.81	0.39	1.58
October	0.14	2.32	0.30	1.62
November	0.15	3.09	0.28	1.55
December	0.29	3.90	0.31	1.43
Spring	0.16	1.66	0.39	1.65
Summer	0.10	1.53	0.41	1.72
Fall	0.13	2.41	0.32	1.58
Winter *	0.29	3.90	0.31	1.43
Annual	0.14	1.68	0.37	1.63

* December only

IV. VEGETATION CHEMISTRY

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ABSTRACT

The construction of two 300 megawatt coal-fired power plants four miles north of the Montana border prompted the initiation of various air quality studies in the Poplar River area. The power plants being built near Coronach, Saskatchewan are expected to be large sources of various trace elements which could affect the vegetation of the northeastern Montana area. Background samples of various vegetation types were taken and analysed for various elements. Sample collection methods, analysis procedures, and results are presented in the report. Recommendations are made for a second sample collection and analysis after the power plants have been operating for several years.

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I. INTRODUCTION

The construction of two 300 megawatt coal-fired power plants near Coronach, Saskatchewan prompted various air quality studies in northeastern Montana. The area of concern is the Poplar River area near Scobey, Montana. The Air Quality Bureau of the Montana Department of Health and Environmental Sciences initiated or increased air quality related studies of ambient air quality, meteorology, visibility, vegetation chemistry and soil sampling. This section of the report will concentrate on one phase of those studies - vegetation chemistry.

II. SAMPLE COLLECTION AND PREPARATION

A. Collecting the Sample

The forage sample was representative of the site with respect to the relative abundance and growth habits of the various species. In choosing these plants care was taken to avoid harvesting tissue which might not give representative data. For example, samples from plants infected with a fungus disease were not chosen for analysis.

Forage samples were cut 2 to 3 inches above the ground in order to be representative of the portion harvested or consumed and to avoid soil contamination. The amount of sample taken was approximately 200 gram composite (if possible).

If an entire field was sampled, small aliquots were cut every 15 steps along the "U" shaped path covering most of the field.

B. Care and Preparation of the Vegetation Sample

1. Identification of Sample

The collected sample was placed in a properly coded paper bag.

All pertinent information was included with the sample, including date and time of day sampled, location and specific map reference, names of sampling personnel, plant species and description of tissue, weather conditions and any unusual local factor.

2. Wet vegetation was avoided.

3. Samples were dried for 24 hours at 80°C, ground to pass a 40-mesh screen and thoroughly mixed. Aliquots for analysis should be obtained by riffling. (Note - most methods of drying samples use either air drying or oven drying and no mention is made of elements escaping).

III. VEGETATION ANALYSIS METHODS

A. Cadmium and Lead

The following consists of the analysis method used by the Air Quality Bureau for cadmium and lead:

Weigh out one gram of sample into 125 ml Phillips beaker. Add 10.0 ml of redistilled concentrated HNO_3, cover with watch glass, let stand for half hour. Then add 3 ml of 70-72% $HCLO_4$. The covered samples are taken to perchloric fumes on a hot plate. The samples are then cooled and brought to volume in 10 ml volumetric flask with distilled deionized water. The samples are mixed well by stopping and inverting 10-15 times. Let stand for one hour before analyzing samples and standards (.05-5 ppm for lead, .001 to 1 ppm for Cd) by Atomic Absorption Spectroscopy.

B. Boron

The following consists of the analysis method used by the Air Quality Bureau for boron:

Weigh out 3 grams of sample into a porcelain casserole. Add .3 grams of calcium oxide powder and mix well. Char on a hot plate for one hour. Transfer porcelain casserole to muffle furnace at 500° to 550°C for two hours, cool and moisten with water. Cover with porcelain cover, introduce 9 ml of 1-1 hydrochloric acid which should make the solution strongly acid and heat on a steam bath for 30 minutes. Filter and wash the residue with distilled deionized water and dilute to 50 ml volume. Pipet 2 ml of samples and standards into boron free beaker. Add 10 ml of concentration H_2SO_4 to each beaker, mix, and cool. Add 10 ml of Carmine reagent, (Carmine 0.920 gm/l in concentrated H_2SO_4). Shake until completely dissolved. Mix and allow to stand at least 45 minutes for color development. Determine colorimetrically at a wavelength of 585 millimicrons.

C. Arsenic and Selenium

The following consists of the analysis method used by the Air Quality Bureau for arsenic and selenium:

Weigh out 0.5 gram of sample into a 125 ml Phillips beaker. Add 6 ml of concentrated HNO_3 and 5 ml of concentrated H_2SO_4. Cover with a watch glass and heat on hot plate until H_2SO_4 fumes appear. Cool and dilute to 25 ml with distilled deionized water. Pipet 10 ml sample into a large culture tube. The samples and standards are analyzed by Atomic Absorption Spectroscopy with hydride vapor generation.

D. Fluoride

The following consists of the analysis method used by the Air Quality Bureau for fluoride:

Weigh out 0.5 gram of sample into an inconel crucible. Add 0.1 gram of CaO low in fluoride and 5 ml of distilled deionized water to make a loose slurry. Add two drops of phenolphthalein solution. Mix with a polyethylene policeman. Final mixture should be red. Place crucible under IR lamps, evaporate to dryness. Transfer crucible to hot plate and char for 1 hour. Then place crucible in muffle furnace at 600°C for 1 hour. Remove crucibles (no more than 8 at one time), add 3 grams of NAOH pellets, and replace for 2 minutes in furnace with door closed. Remove crucibles individually and swirl to suspend particulate matter until melt is partially solidified. Let cool, then add 5 ml of distilled deionized water. Slowly add 5 ml of 1-1 $HClO_4$ to the samples. Repeat three more times. Transfer sample with H_2O to a plastic tube graduated at 50 ml. Rinse crucible three times with H_2O and dilute to 50 ml with H_2O.

The samples and standards are analyzed by using the automated Alizarin fluoride blue complexone method.

E. Sulfur

The following summarizes the analysis method used by the Air Quality Bureau for analysis of sulfur:

A Parr oxygen colorimeter bomb has been employed successfully for quantitative decomposition of organic samples. Water is introduced into the bomb prior to combustion and the resulting combustion products are absorbed in the water. This aqueous liquid may then be analyzed for trace quantities of the desired cation or anion by standard microanalytical methods. The specific analysis is as follows: Place about 0.1 gram of sample in the pellet maker. Apply pressure to make a pellet. Weigh Parr bomb crucible. Place pellet in the crucible, reweigh. Subtract the difference for weight of sample. Wet the sample with two drops of methanol.

Place ignition wire over the sample. Add 2.5 ml of H_2O and 2.5 ml of 3% H_2O_2 to the bomb. Assemble bomb and introduce 35 atmospheres of oxygen. During the actual firing, the bomb is immersed in a cold water bath. After combustion, quantitatively transfer the aqueous portion with distilled deionized H_2O to a plastic centrifuge tube graduated at 50 ml. Adjust the volume to 50 ml with H_2O.

The samples and standards are analyzed by using the automated Methylthymol blue method for sulfate.

F. Nitrogen

Analysis was not performed for nitrogen as was originally expected prior to the study. A list was compiled prior to the study of the elements that were expected to be emitted by the power plants and that could be readily analyzed by the Air Quality Bureau. Nitrogen was originally entered on this list. However, it was later noted that a significant portion of the fields in the Poplar River area were fertilized with nitrogen and other compounds. It was felt by the Air Quality Bureau that any analysis for nitrogen would be erroneous for that reason.

IV. RESULTS

The map in Figure 1 shows the approximate locations of the vegetation sampling sites. A more accurate description of the sampling sites is given in the appendix. Table 1 shows the results of the analyses of the first sample series taken (early summer 1977). Table 2 shows the results for the second sample series taken (late summer 1977). The only noteworthy value is the selenium for site 4 and 8 of the first collection. These values were rechecked by second analyses and appear to be correct.

The following lists the quality control data for the duplicate and spiked samples:

The following were duplicated for sulfur

site #5 alfalfa 1st collection 5655 and 5632 ug/g

site #11 alfalfa 1st collection 4350 and 4344 ug/g

site #8 grasses and forbs 2nd collection 3163 and 3163 ug/g

These were spiked for sulfur with 1 ml of 1000 ug/ml sulfate

site #5 alfalfa 1st collection recovery was 109%

site #11 alfalfa 1st collection recovery was 101%

site #8 grasses and forbs 2nd collection recovery was 94%

The following were duplicated for fluoride

site #10 grasses 1st collection <1.0 and <1.0 ug/g

site #11 alfalfa 1st collection 1.0 and 1.0 ug/g

site #1 alfalfa 2nd collection 1.0 and 1.0 ug/g

site #5 spring wheat and wild oat heads 2nd collection <1.0 and <1.0

site #12 grasses 2nd collection <1.0 and <1.0 ug/g

site #12 spring wheat head 2nd collection <1.0 and <1.0 ug/g

These were spiked for fluoride with 100 ug/ml fluorides

site #10 grasses 1st collection recovery was 103%

site #11 alfalfa 1st collection recovery was 96%

site #1 alfalfa 2nd collection recovery was 95%

site #12 spring wheat head 2nd collection recovery was 95%

The following were duplicated for lead

site #5 spring wheat 1st collection .50 and .50 ug/g

site #9 grasses and forbs 1st collection .60 and .60 ug/g

site #14 grasses and forbes 1st collection <.10 and <.10 ug/g

site #1 grasses and forbs 2nd collection 1.00 and 1.00 ug/g

site #10 grasses and forbs 2nd collection .80 and .20 ug/g

site #12 spring wheat stems 2nd collection 2.00 and 2.00 ug/g

These were spiked for lead with 2 ml of 1 ug/ml lead

site #5 spring wheat 1st collection recovery was 95%

site #9 grasses and forbs 1st collection recovery was 85%

site #14 grasses and forbs 1st collection recovery was 70%

site #1 grasses and forbs 2nd collection recovery was 94%

site #10 grasses and forbs 2nd collection recovery was 90%

site #12 spring wheat stems 2nd collection recovery was 79%

The following were duplicated for cadmium

site #5 spring wheat 1st collection .13 and .13 ug/g

site #9 grasses forbs 1st collection .43 and .42 ug/g

site #14 grasses and forbs 1st collection .09 and .12 ug/g

site #1 grasses and forbs 2nd collection .21 and .21 ug/g

site #12 spring wheat stems 2nd collection .01 and .01 ug/g

These were spiked for cadmium with 5 ml of 1 ug/ml cadmium

site #5 spring wheat 1st collection recovery was 94.4%

site #9 grasses and forbs 1st collection recovery was 98.4%

site #14 grasses and forbs 1st collection recovery was 95%

site #1 grasses and forbs 2nd collection recovery was 94%

site #10 grasses and forbs 2nd collection recovery was 106%

site #12 spring wheat stems 2nd collection recovery was 111%

The following were duplicated for boron

site #8 grasses and forbs 1st collection 12.83 and 13.67 ug/g

site #9 grasses and forbs 1st collection 18.67 and 18.67 ug/g

site #1 alfalfa 2nd collection 50.12 and 50.33 ug/g

site #5 grasses and forbs 2nd collection 40.00 and 40.00 ug/g

site #10 spring wheat stems 2nd collection 4.67 and 4.67 ug/g

site #12 alfalfa 2nd collection 41.33 and 41.17 ug/g

These were spiked for boron with 2 ml of 100 ug/ml of boron

site#8 grasses and forbs 1st collection recovery was 101%

site #9 grasses and forbs 1st collection recovery was 100%

site #5 alfalfa 2nd collection recovery was 93.5%

site #11 alfalfa 2nd collection recovery was 88.0%

site #12 spring wheat stems 2nd collection recovery was 89.3%

The following were duplicated for arsenic

site #4 grasses and forbs 1st collection <.05 and <.05 ug/g

site #11 grasses and forbs 1st collection <.05 and <.05 ug/g

site #1 spring wheat heads 2nd collection <.05 and <.05 ug/g

site #9 grasses and forbs 2nd collection <.05 and <.05 ug/g

These were spiked for arsenic with 3 ml of .1 ug/ml arsenic

site #1 alfalfa 1st collection recovery was 43.1%

site #13 alfalfa 1st collection recovery was 4%

site #11 grasses and forbs 2nd collection recovery was 14.2%

site #12 grasses and forbs 2nd collection recovery was 12.5%

The following were duplicated for selenium

site #4 grasses and forbs 1st collection 76.88 and 91.25 ug/g

site #8 grasses and forbs 1st collection 86.87 and 75.00 ug/g

site #11 grasses and forbs 1st collection .25 and .25 ug/g

site #1 spring wheat heads 2nd collection .32 and .65 ug/g

site #9 grasses and forbs 2nd collection .38 and .40 ug/g

These were spiked for selenium with 3 ml of 1 ug/ml selenium

site #1 alfalfa 1st collection recovery was 0%

site #13 alfalfa 1st collection recovery was 40.6%

site #4 grasses and forbs 2nd collection recovery was 18%

site #12 spring wheat heads 2nd collection recovery was 62.5%

Table 3 shows the quality control data of the vegetation analyses. These are the analyses performed on reference material as a comparison with certified values of the National Bureau of Standards. The results show a very close comparison except under boron. The boron analyses of the reference material were two-thirds of the certified value.

V. SUMMARY AND RECOMMENDATIONS

Samples of various vegetation types were collected and analyzed for two stages in the vegetation growth. The samples were collected at various directions and distances from the Poplar River Power

Plants near Coronach, Saskatchewan. Results of the analyses are presented along with spiked and duplicate samples and quality control results.

Recommendation is made for further investigation of two sites that had high selenium values in the first sample collection. These values may be the results of something being introduced locally by the landowner. It is further recommended that samples be collected from the same locations after the power plants have operated for some time to determine if the trace element levels have changed.

APPENDIX

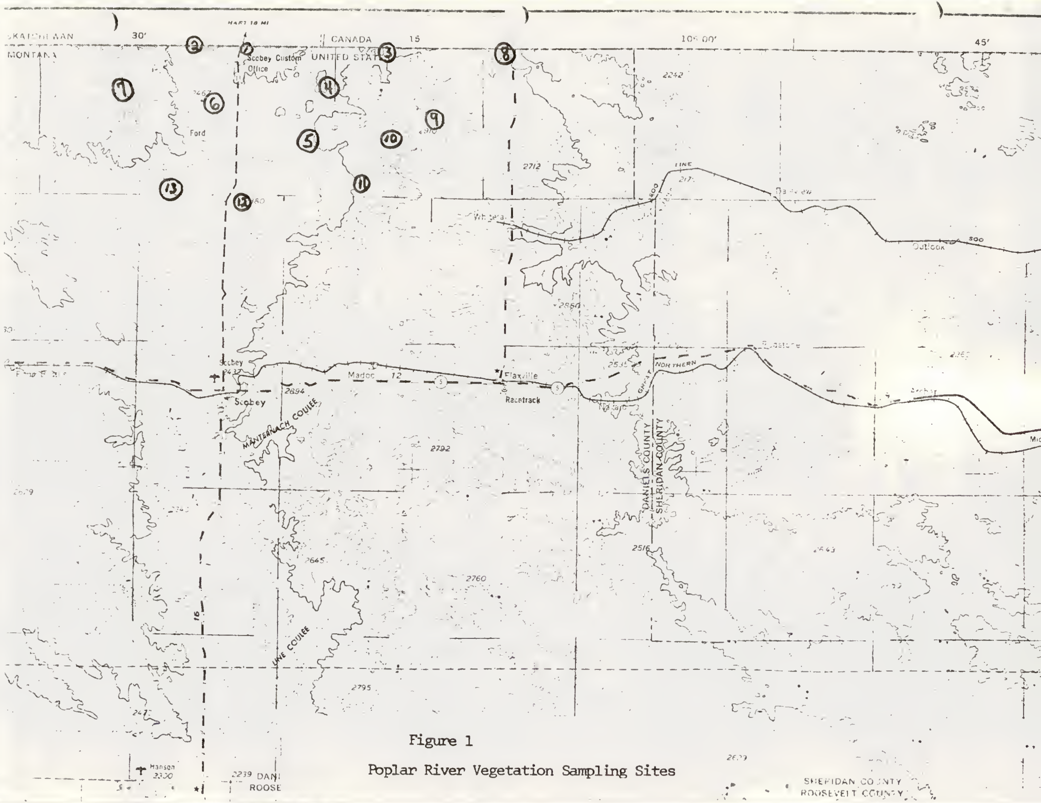

Figure 1

Poplar River Vegetation Sampling Sites

Table 1
Poplar River Vegetation Analyses
First Collection(all values in ug/g dry weights)

	F	B	Pb	Cd	S	As	Se
Site #1							
Spring Wheat	2.0	1.17	.70	.13	2646	<.05	.14
Grasses & Forbs	3.0	13.33	.70	.05	2071	.06	.12
Alfalfa	<1.0	55.33	.60	.05	4627	.06	.12
Site #2							
Grasses & Forbs	<1.0	4.50	.90	.25	5064	<.05	1.32
Spring Wheat	<1.0	2.33	.10	.13	4426	<.05	.14
Site #3							
Spring Wheat	1.0	7.00	.10	.13	4154	.06	.14
Grasses & Forbs	<1.0	13.33	.10	<.05	2798	<.05	.25
Site #4							
Grasses & Forbs	2.0	39.17	.10	.20	4540	<.05	84.06
Site #5							
Spring Wheat	7.0	46.83	.50	.13	5786	.06	.14
Grasses & Forbs	2.0	38.67	.50	.15	5164	<.05	.13
Alfalfa	2.0	67.0	.20	<.05	5644	.05	<.05
Site #6							
Grasses & Forbs	2.0	36.0	.50	.15	5365	<.05	.18
Site #7							
Grasses & Forbs	1.0	13.33	1.11	.08	3031	.05	.14
Spring Wheat	<1.0	2.33	.20	<.05	3085	<.05	.25
Site #8							
Grasses & Forbs	3.0	13.25	.20	.08	3885	<.05	80.93
Site #9							
Grasses & Forbs	4.0	18.67	.60	.43	3652	<.05	1.25
Site #10							
Grasses	<1.0	4.67	.60	.01	2121	<.05	.19
Spring Wheat	<1.0	15.83	.90	.03	4246	<.05	.05
Site #11							
Grasses & Forbs	<1.0	20.00	.10	.23	7117	<.05	.25
Alfalfa	1.0	40.50	.40	.07	4347	<.05	<.05
Site #12							
Spring Wheat	<1.0	43.83	.90	.04	4708	<.05	.22
Alfalfa	<1.0	.40	.40	.03	3493	<.05	.25
Grasses & Forbs	<1.0	27.66	.60	.09	5097	<.05	.22

	F	B	Pb	Cd	S	As	Se
Site #13							
Grasses	<1.0	4.67	.10	.01	2463	<.05	.92
Alfalfa	<1.0	27.17	.10	.03	2442	<.05	.35
Site #14							
Grasses & Forbs	9.0	16.17	<.10	.17	3398	<.05	.88
Spring Wheat	<1.0	2.00	<.10	.03	4450	<.05	.19

Less than equals the minimum detectable amount or the detection limit.

Table 2
Poplar River Vegetation Analyses
Second Collection(all values in ug/g dry weight)

	F	B	Pb	Cd	S	As	Se
Site #1							
Grasses & Forbs	1.0	<1.66	1.00	.10	2179	.10	.25
Alfalfa	1.0	50.22	1.00	.11	2776	.08	.30
Spring wheat stems	1.0	<1.66	1.00	.21	1746	<.05	.38
Spring wheat heads	<1.0	<1.66	67.6	.11	2101	<.05	.49
Site #2							
Grasses & Forbs	<1.0	11.67	1.00	.15	3272	<.05	.52
Spring wheat stems	<1.0	<1.66	1.00	.26	2700	.06	.08
Spring wheat head	<1.0	<1.55	31.5	.16	877.8	<.05	.08
Site #3							
Grasses & Forbs	3.0	12.50	1.00	.11	4248	<.05	.08
Site #4							
Grasses & Forbs	1.0	25.00	1.20	.16	3070	.06	.17
Site #5							
Grasses & Forbs	<1.0	40.00	8.30	.10	3747	<.05	.11
Alfalfa	<1.0	46.83	.20	<.05	6795	<.05	.08
Spring wheat & wild stem oats	<1.0	31.67	1.20	<.05	5775	<.05	.16
Spring wheat & wild oat heads	<1.0	1.83	9.40	<.05	804	<.05	.25
Site #6							
Grasses and Forbs	1.0	28.33	2.60	<.05	3063	.06	.12
Site #7							
Grasses	5.0	11.83	.40	.22	3419	.12	.22
Spring wheat stems	<1.0	3.67	.90	<.05	1665	.05	.10
Spring wheat heads	<1.0	4.67	14.90	<.05	692	<.05	.40
Site #8							
Grasses & Forbs	1.0	17.50	.20	.14	3163	<.05	.15
Site #9							
Grasses & Forbs	1.0	11.83	.80	.32	3188	<.05	.380
Site #10							
Grasses & Forbs	3.0	15.00	.50	.21	3377	.17	.24
Spring sheat stems	<1.0	4.67	.60	.16	3772	.20	.14
Site #11							
Grasses & Forbes	<1.0	7.00	< .50	.05	3390	<.05	.07
Alfalfa	<1.0	45.50	.50	.05	6056	<.05	.07

	F	B	Pb	Cd	S	As	Se
Site #12							
Grass	<1.0	36.33	.50	.06	7091	.12	.05
Alfalfa	<1.0	41.33	1.0	.14	1694	<.05	.35
Spring wheat stems	<1.0	1500	2.0	.01	2125	.15	.24
Spring wheat head	<1.0	4.67	14.10	.01	1072	.06	.35
Site #13							
Grasses	<1.0	6.67	<.50	.05	1473	<.05	.44
Alfalfa	<1.0	34.16	.60	.05	6193	<.05	.22
Site #14							
Grasses & Forbs	4.0	25.33	.70	.25	3673	<.05	.44
Spring wheat stems	<1.0	10.16	.60	.35	1100	.13	.36
Spring wheat head	<1.0	4.57	35.4	.05	707	<.05	.85

Less than equals the minimum detectable amount or the detection limit.

Table 3

Poplar River Quality Control Data
National Bureau of Standards
Standard Reference Material: Comparison of Certified values with the Montana State Department of Health and Environmental Sciences values
Certified of Orchard Leaves NBS 1571

(all values ug/g)

Element	certified value by NBS	SDHES value
Pb	45± 3	48.07 ± 2.41
Cd	.11 ± .02	.11 ± .02
B	33 ± 3	21.00 ± .59
As	11 ± 2	11.50
Se	0.08 ± .01	.05

Non-certified Orchard Leaves NBS 1571

F	4	3 ± .82
S	2300	2304 ± 102

Certified of Tomato Leaves NBS 1573

As	.27 ± .05	.25

Non-certified Tomato Leaves NBS 1573

B	30	25.00

VEGETATION SAMPLING SITES

Site No. 1

General Location: Port of Scobey

Site Description: R 48 E, T 37 N, Sec. No. 4, International boundary zone, 168 yds E of highway adjorning grass airstrip, (10 ft S).

Sample Type: Grain, alfalfa

Site No. 2

General Location: 2 mi W of Port of Scobey

Site Description: R 48 E, T 37 N, Sec. No. 6, On U.S. border between several wheat fields on strip of grass in international zone. 2 mi W of Port of Scobey, 100 ft E of intersection of road center and border.

Sample Type: Grain

Site No. 3

General Location: U.S. Border NE SiMerrell Slough

Site Description: R 48 E, T 37 N, Sec. No. 5, U.S. border zone approximately 1 mi ENE of Si Merrell Slough, samples taken 8 ft. S of border fence, bordered on N by grain field, on S,W,E by grassland.

Sample Type: Grain, Natural vegetation, Trees

Site No. 4

General Location: Dale Marlenee land

Site Description: R 48 E, T 37 N, Sec. No. 12, On Dale Marlenee land approximately 1½ mi S of U.S. border, samples taken 26 ft N of fence approximately ½ mi N of main road, bordered on S by grainfield N,E,W by unused grass - slough.

Sample Type: Grain, Natural vegetation, Alfalfa near main road

Site No. 5

General Location: Boyd Tymofichuk land

Site Description: R 48 E, T 37 N, Sec. No. 23, On Boyd Tymofichuk land approximately 3/4 mi SSW of Jagiello Waterfowl Production area, samples taken 20 ft W of fence and 30 S of trail in natural vegetation land, grain fields border on 3 sides (N,E,S) with natural vegetation land on W, alfalfa field within ¼ mi W.

Sample Type: Grain, Alfalfa, Natural vegetation

Site No. 6A

General Location: Robert Tymofichuk

Site Description: R 47 E, T 37 N, Sec. No. 13, On Robert Tymofichuk land, 100 yds SW of buildings.

Sample Type: Alfalfa

Site No. 7

General Location: Boyd Tymofichuk land 1½ mi S border

Site Description: R 47 E, T 37 N, Sec. No. 10, On Boyd Tymofichuk land 1½ mile S of U.S. border, samples taken 53 ft (start) E of fence transect moving S, site in middle of grassland, strip wheat fields nearby all sides.

Sample Type: Grain, Natural vegetation

Site No. 8

General Location: Whitetail Border Station

Site Description: R 50 E, T 37 N, Sec, No. 6, On international boundary zone 1/3 mile W of Whitetail border station, samples taken 20 ft S of fence, bordered on S by grain field and on other 3 sides by grassland.

Sample Type: Grain, Natural Vegetation

Site No. 9

General Location: Fred LaCombe land

Site Description: R 49 E, T 37 N, Sec. No. 14, On Fred LaCombe land approximately 2¼ mi S of border, samples taken on hillside (northern exposure) start of transect 10 ft from fence moving toward farmhouse. bordered on all sides by grassland.

Sample Type: Natural vegetation, Grain, Pine-at farm house

Site No. 10

General Location: Mary Sain Residence

Site Description: R 49 E, T 37 N, Sec. No. 20, On Anton Sain pasture north of farm house, 8 yds S of fence approximately 500 yds N of farm house 75 yds E of fence (line along S fence), area surrounded on N, W & S by stripped wheat fields, area E pasture with cattle.

Sample Type: Grain , Trees

Site No. 11

General Location: Floyd Engberg Residence

Site Description: R 49 E, T 37 N, Sec. No. 31, On Floyd Engberg field E of house alfalfa and brome, 125 ft N of marked fence post, ¼ mi E of house, area S is more grassland (also W,E), area N is stripped wheat field.

Sample Type: Brome grass, Alfalfa, Grain, Trees

Site No. 12

General Location: Chabot land

Site Description: R 48 E, T 36 N, Sec. No. 11, On Chabot land, (farmed by Boyd Tymofichuk), alfalfa field bordering E. Fk. Poplar River, ½ mi SE of old bridge, 70 ft E of old flue (wooden).

Sample Type: Alfalfa, Grain

Site No. 13

General Location: Buer land 2 mi W E. Fk. Poplar River

Site Description: R 47 E, T 37 N, Sec. No. 36, On Frieda and Mabel Buer land 2 mi W of E Fk. Poplar River, sample taken in bottom land (alfalfa and grass), transect started 100 ft N of fence and moving N, bordered on all sides by grain fields.

Sample Type: Alfalfa, Grain

Site No. 14 (Background - control data)

General Location: Ernest Fouhy land near Butte Creek

Site Description: R 45 E, T 36 N, Sec. No. 19, On Ernest Fouhy land near Butte Creek, samples taken 200 ft S of telephone pole in field (unbroken) ½ mi NE of house (near creek bottom) 200 ft W.

Sample Type: Alfalfa, Grain, Natural vegetation

V. SOIL SAMPLING

Project Officer
Warren Norton

Written By
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Helena, Montana 59601

ABSTRACT

The proposed 300 megawatt power plants to be built near Coronach, Saskatchewan, prompted various background studies to be conducted in northeastern Montana. One such study was to sample existing soil at various locations and store these for future analysis. If trace element effects are noted in the vegetation in future years, the soil will be analyzed to determine the changes that have occurred. Two identical series of soil samples were stored. One was stored at the Air Quality Bureau and one at Montana State University. Descriptions of sampling techniques and site locations are given.

I. INTRODUCTION

When Saskatchewan Power announced plans to build a power plant within two miles of the international boundary north of Scobey the people of the area became concerned with the possible effects of air pollution in their area. One concern was that the stack gas effluent from the plant would fall out on the soils of the area down wind from the plant and possibly affect the crop growing capacity of the soil. People of the area suggested that soil analysis be done to provide data on the natural trace elements in the soil prior to the operation of the power plant. In reviewing this proposal the Environmental Protection Agency, Region VIII Denver and Montana State Department of Health felt that soil analysis was a very poor way to evaluate air pollution problems. The naturally occurring amount of trace elements in the soil vary a large amount even within a relatively small area. This makes the detection of trace elements from a stack gas plume in a soil matrix extremely difficult. Also it was felt that the effects of air pollution would show up in the vegetation of the area long before it would be detectable in a soil sample. For these reasons it was decided to place more emphasis on the vegetation analysis at this time.

II. STUDY DESIGN

In order to cover the possibility of an air pollution impact on the soil of the Scobey area the Montana Department of Health proposed that soil samples be taken prior to start up of the power plant. These samples would provide background data for comparison if it were determined at a later date that the soil had been affected. These samples were taken in May, 1977. They were brought back to Helena where the samples were dried, split into two sets, and sealed in polyethylene bottles. The sample bottles are labeled on the bottle with a magic marker and on label tags attached with wire fasteners around the neck of the bottle. One set is stored in the Montana Air Quality Bureau's sample storage cabinet in the basement of the Cogswell Building in Helena. The other set was transferred to the Montana State University Soil Bank, Department of Plant and Soil Science, Bozeman, Montana.

III. SAMPLING PROCEDURES

General site selection was determined by use of meteorological parameters; these sites were placed downwind from the stack on the four, six, and ten mile radii (Figure 1). The actual sample site was selected by the sampling team with consideration given to the following conditions:

1. In order to assess the impact of stack gases on soils, it was felt that the soil samples had to be taken from uncultivated soils. This is due to the high and variable content of numerous trace elements in almost every type of soil; and any addition of trace elements from a stack gas plume would be in a very fine layer on the surface. If this surface layer was mixed with six to eight inches of soil, as is done in plowing and cultivation, the element we would be looking for would be lost in the background variability of the natural soil.

2. For accurate site locations, the soil sampling sites were chosen where possible along fence lines or in fence corners, but at least 100 yards away from the nearest road. This presents a problem also in that metals such as iron, zinc and cadmium are found in high concentrations in soils under fence wire due to oxidation and weathering of the metal in the wires. This effect is, however, restricted to within six to twelve inches of the fence line. Areas were found between cultivated ground and fence lines to locate sample sites. When this area was not available, then pasture ground, fence corners, or other areas were used.

3. A sample site consisted of a transect or line approximately one hundred yards long. One end of the transect was identified by a metal identification tag placed on a nearby fence post or telephone pole where available. The sample site is also located on seven and one half minute series U.S.G.S. maps of the area, with location notes on the maps. These maps and notes were stored with the samples.

4. A sample core was taken every two steps along the transect so that each sample will consist of 30 to 50 cores. The core sampler was marked at the three inch depth. The core sampler was inserted into the ground until the mark was even with the top of the mineral surface. The core was then extracted and divided into two parts. The mat, or duff, which is the dead organic matter laying on top of the ground, plus the top one inch of soil was the first section, and the bottom one inch was the last section of each three

inch core. The mat, when available, acts as a very good filter and would probably be the first portion of soil sample to show a difference due to air pollution. However, in the Scobey area very little mat was found at most sites, so the mat was included with the top one inch of soil. Therefore the first section included one full inch of soil plus any duff that may have been at a particular site. The top one inch should show any difference caused by fallout from the stack gas plume. The bottom one inch of the three inch core sample should provide a common base or background factor to compare with values from the mat or the top one inch of soil. Any difference then could be attributed to the atmospheric impact on the soil.

5. As each core was extracted, the top one inch of mat and soil was separated and put into one sample container, and the bottom one inch into another. Thus, each site generated two composited samples. The core section in between was discarded. Thirty to fifty cores were obtained for each sample; maximum sample size was limited to that number of core sections which would fill a one-quart container.

6. The samples were then air dried immediately and returned as soon as possible to the laboratory in Helena for storage preparation. This consisted of oven drying the samples for 24 hours at a temperature between 100 and 110°C. These drying temperatures would be expected to vaporize some mercury, selenium and fluoride compounds if they were present. Each sample was then crushed in a porcelain mortar and pestle, thoroughly mixed to assure homogeneity, and split into two identical portions in a stainless steel splitter. This

made two identical sets of samples. Both sets were transferred to polyethylene containers with labels attached. One set was transported to Bozeman for storage in the Montana State University soil bank. The other set was stored in the Air Quality Bureau sample storage cabinet in the basement of The Cogswell Building in Helena.

IV. SUMMARY AND RECOMMENDATIONS

Soil samples were taken in the Scobey area in May, 1977, for the purpose of establishing a baseline of naturally occurring trace elements in the soil. These samples have been documented as to location, sampling and preparation method, and have been stored in the Montana State University Soil Bank. These samples will be available for analysis at any time that it can be determined that the stack gas plume has affected the soils down wind of the plant.

APPENDIX

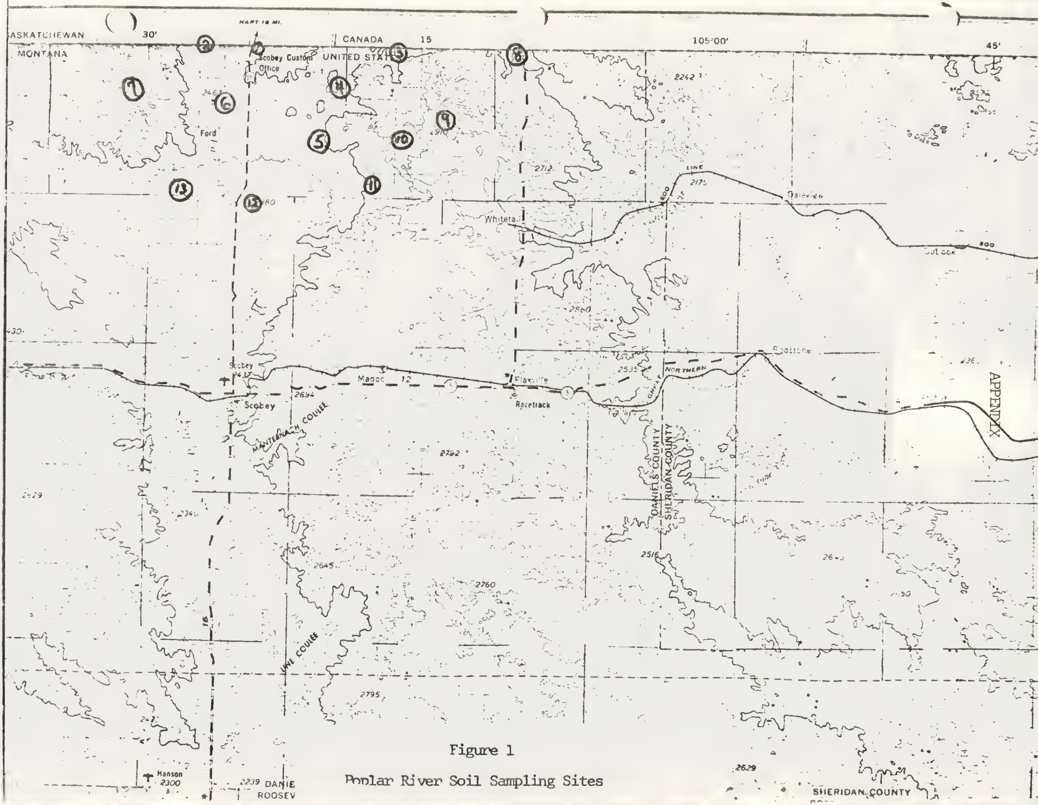

Figure 1

Poplar River Soil Sampling Sites

SOIL SAMPLING SITES

Site No. 1

General Location: Port of Scobey

Site Description: R 48 E, T 37 N, Sec. No. 4, International boundary zone, 168 yds E of highway adjoining grass airstrip (10 ft S).

Site No. 2

General Location: 2 mi. W of Port of Scobey

Site Description: R 48 E, T 37 N, Sec. No. 6, On U.S. border between several wheat fields on strip of grass in international zone. (100 ft E of intersection of road center and border).

Site No. 3

General Location: U.S. Border NE SiMerrel Slough

Site Description: R 49 E, T 37 N, Sec. No. 5, U.S. Border Zone approximately 1 mi ENE of Si Merrell Slough, samples taken 8 ft S of border fence, bordered on N by grain field, on S,W,E by grassland.

Site No. 4

General Location: Dale Marlenee land

Site Description: R 48 E, T 37 N, Sec. No. 12, On Dale Marlenee land approximately 1½ mi. S of U.S. Border, samples taken 26 ft. N of fence approximately ½ mi. N of main road, bordered on S by grain field, N,E,W, by unused grass - slough.

Site No. 5

General Location: Boyd Tymofichuk land

Site Description: R 48 E, T 37 N, Sec. No. 23, Boyd Tymofichuk land approximately 3/4 mi SSW of Jagiello Waterfowl Production area, samples taken 20 ft W of fence and 30 S of trail in natural vegetation land, grain fields border on 3 sides (N,E,S) with natural veg. land on W alfalfa field within ¼ mi. W.

Site No. 6

General Location: Robert Miller land

Site Description: R 48 E, T 37 N, Sec. No. 17, On Robert Miller land bordering E Fork Poplar River, 100 ft E of telephone pole (2nd from intersection).

Site No. 7

General Location: Boyd Tymofichuk land 1½ mi S border

Site Description: R 47 E, T 37 N, Sec. No. 10, On Boyd Tymofichuk land 1½ mile S of U.S. Border, samples taken 53 ft (start) E of fence transect moving S, site in middle of grassland, strip wheat fields nearby all sides.

Site No. 8

General Location: Whitetail Border Station

Site Description: R 50 E, T 37 N, Sec. No. 6, On international boundary zone 1/3 mile W of Whitetail Border Station, samples taken 20 ft S of fence, bordered on S by grain fields and on other 3 sides by grassland.

Site No. 9

General Location: Fred LaCombe land

Site Description: R 49 E, T 37 N, Sec. No. 14, On Fred LaCombe land approximately 2¼ mi S of border, samples taken on hillside (northern exposure) start of transect 10 ft from fence moving toward farmhouse. Bordered on all sides by grassland.

Site No. 10

General Location: Mary Sain Residence

Site Description: R 49 E, T 37 N, Sec. No. 20, On Anton Sain land, pasture N of farm house, 8 yds S of fence, approximately 500 yds N of farmhouse, 75 yds E of fence (line along S fence), area surrounded on N, W & S by stripped wheat fields, area E pasture with with cattle.

Site No. 11

General Location: Floyd Engberg Residence

Site Description: R 49 E, T 37 N, Sec. No. 31, On Floyd Engberg land, field E of house alfalfa and brome, 125 ft N of marked fence post ¼ mi E of house, area S is more grassland (also W,E), area N is stripped wheat field.

Site No. 12

General Location: Chabot land

Site Description: R 48 E, T 36 N, Sec. No. 11, On Chabot land (farmed by Boyd Tymofichuk), alfalfa field bordering E Fk. Poplar River, ½ mi SE of old bridge, 70 ft E of old flue (wooden).

Site No. 13

General Location: Buer land 2 mi W E. Fk. Poplar River

Site Description: R 47 E, T 37 N, Sec. No. 36, On Frieda and Mabel Buer land 2 mi W of E Fk. Poplar River, Sample taken in bottom land (alfalfa and grass), transect started 100 ft N of fence and moving N, bordered on all sides by grain fields.

Site No. 14 (Background - control site)

General Location: Ernest Fouhy land near Butte Creek

Site Description: R 45 E, T 36 N, Sec. No. 19, On Ernest Fouhy land near Butte Creek, samples taken 200 ft S of telephone pole in field (unbroken) ½ mi NE of house (near creek bottom) 200 ft W.